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The Commonwealth of Massachusetts.

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A REPORT

UPON

THE SCALLOP FISHERY

OF

MASSACHUSETTS,

INCLUDING THE HABITS, LIFE HISTORY OF *PECTEN IRRADIANS*,
ITS RATE OF GROWTH, AND OTHER FACTS OF
ECONOMIC VALUE.



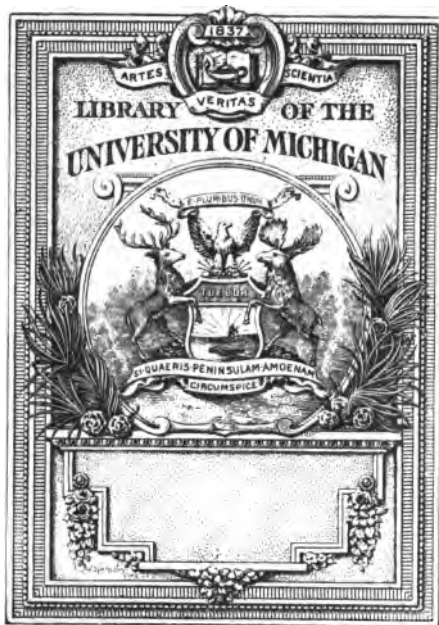
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Massachusetts, Commission on
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The Commonwealth of Massachusetts.

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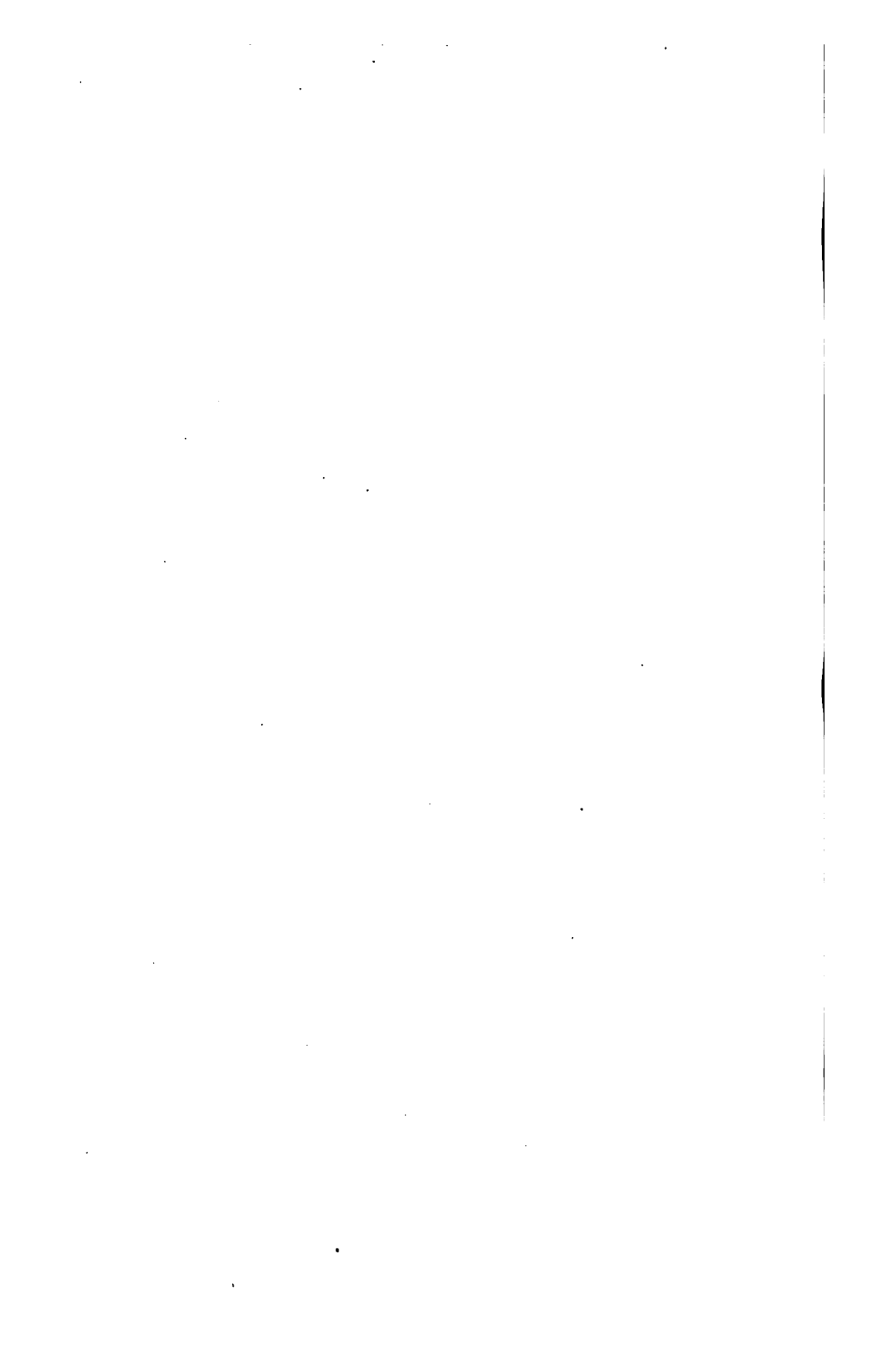
COMMISSIONERS ON FISHERIES AND GAME,
STATE HOUSE, BOSTON, Sept. 15, 1910.

To the Honorable Senate and House of Representatives.

We herewith transmit a special report upon the scallop fishery of Massachusetts, as directed by chapter 74, Resolves of 1906. The complementary portion relating to the lobster fishery is embodied in a separate report.

Respectfully submitted,

GEORGE W. FIELD.
JOHN W. DELANO.
GEORGE H. GARFIELD.



A REPORT UPON THE SCALLOP FISHERY OF MASSACHUSETTS.

The bays, estuaries and tidal flats of New England are practically undeveloped as sources of food. The demands and conditions of an increased population, far surpassing the dreams of the framers of the colonial laws, have in a very great degree destroyed the delicately adjusted balance of animal life in these waters, and left us only a comparatively barren waste, governed by laws far out of tune with the changed conditions. The waters are capable of producing for man as much "sea food" as formerly, possibly more, but certainly an enormous increase over present supply if the laws could be so amended as to permit the cultivation of the bays and shores to the full capacity, after the scientific agricultural methods already adopted for increasing the yield of the land.

It is a well-established law of economics that increased population increases the demand for food, with consequent higher prices. These higher prices tend to spread to well nigh every branch of living expenses. The fundamental method of checking this undue increase is to increase the supply. We have learned to do this in the case of corn, potatoes, wheat and other agricultural staples, and (apart from uneconomic and often harmful manipulation of prices by speculators) the increased demand brings forth an increased supply. With the supply of game, lobsters, fish, clams, scallops, etc., however, we apply the absurd practice of limiting the demand by restrictive legislation, *e.g.*, close season, size limit, limits upon time of catching or upon quantities to be taken each day, etc., rather than seeking to augment the supply. If the demand for corn or potatoes tends to higher prices, the logical remedy is the production of

more corn and potatoes. We do not call vociferously for a close season on corn or potatoes, or for any other law which tends to restrict the demand. Measures are taken as quickly as possible to augment the supply.

The necessary increased development of our shellfish supply is notoriously prevented by antiquated and inadequate laws. Agriculture cannot flourish where the community must depend either upon natural yields ("volunteer" crops), or upon fields tilled in common by persons whose chief aim is to selfishly appropriate the results "before the other fellow" can.

The capital required for cultivation of the water, aquiculture, is far less than that required for successful cultivation of the land, while the returns per acre are far greater, both in money and in food value of the product. Our shores, therefore, offer remarkable opportunities for the development of shellfish gardens. Here employment could be furnished for many thousands of unskilled laborers, in a healthy and remunerative occupation.

To secure such desirable results the public mind must be disabused of the false idea, almost universally and tenaciously held, that the "public rights" of getting shellfish wherever they may be found is a valuable and inalienable right. It is equally illogical to apply the same reasoning to forest and fruit trees, to strawberries, raspberries and cranberries, making these the property of the person who discovers and markets them, while at the same time making laws which prevent increasing the natural yield through cultivation by individual owners or lessees. The intelligent public cannot fail, however, to see, upon careful and thoughtful consideration, that what has been represented to be a boasted blessing is now in fact a veritable incubus, impeding further progress, and to this are to be traced many of the unfavorable conditions which check the development of our fishing industries and the prosperity of our shore dwellers.

An abundance of "sea food" is a strong attraction to our summer visitors. But the supply must be certain, regular, definite, readily accessible for quick consumption; available in sufficient quantities to meet special seasons of largely increased demand; and produced under unquestionable sanitary conditions.

Further, the supply of bait for our shore fisheries is an exceedingly important item, and should furnish directly large

opportunities for employment, in addition to increasing the quantity of sea fish landed upon our shores.

For these reasons it has seemed wise to the Legislature to devote some attention to the questions involved in the very obvious decline in the shellfish production along our coasts, since this decline affects not alone the shore communities, but, to some degree, every citizen of the State. The problem must be viewed in its broad aspect. The source and the supply of sea food is not solely and exclusively the peculiar asset of the seashore town, to be kept forever closed to development. It should be truly public, in the sense which our forefathers intended, *i.e.*, "free to every citizen of the Commonwealth," free, not for plunder and destruction, but for intelligent development for the increased production of food and wealth.

Inasmuch as the scallop (*Pecten irradians*) and the lobster (*Homarus vulgaris*), though formerly exceedingly numerous and cheap, have now become merely a delicacy, practically beyond the reach of the average citizen, it seemed desirable to investigate for the purpose of suggesting some feasible methods for increasing the market supply, before the source is commercially exhausted.

To say that the fault lies in the increased use of these foods is but idly begging the question. The fault rather lies in the failure to assist Nature, which is ever ready to respond to intelligent and well-directed efforts to increase her bounty.

The report covers in very considerable detail the facts connected with the scallop industry. The notable peculiar fact in the life history, the weak link in the chain of supply, and, therefore, of greatest importance, is that the abundance and even the continuance of the scallop depend chiefly upon the generation immediately preceding. Thus, successful fishing depends upon the number of eggs laid by the previous generation of scallops. The number of eggs laid depends upon how many adults lived through the vicissitudes of the previous winter, after escaping the dredges of the scallopers. As a general rule, the scallop lays but a single litter of eggs, inconceivably vast in numbers, but yet only a single litter. It seems surprising that nature should, so to speak, rest all on a single throw. So narrow, indeed, is the margin of safety that the excessive destruction of scallops

less than one year old, *i.e.*, "seed scallops," may result in complete annihilation of the future supply, — a condition which has occurred in some localities.

The present report is largely the work of the biologist to the commission, D. L. Belding, A.B., and has been carried on upon a broad outline laid out by the chairman, under whose general supervision the work has progressed, in accordance with the provisions of the following resolve: —

ACTS OF 1906, CHAPTER 74.

RESOLVE TO PROVIDE FOR AN INVESTIGATION AND REPORT BY THE COMMISSIONERS ON FISHERIES AND GAME AS TO SCALLOPS AND LOBSTERS.

Resolved, That the commissioners on fisheries and game be authorized and directed to investigate and report upon the life history, feeding and breeding habits of scallops and lobsters, and to make any investigations which may assist in devising methods of commercial propagation of these animals, or of increasing the market supply. The said commissioners are authorized to establish and adequately protect structures and areas of land or water wherein such animals may be kept under observation, and to protect animals or material contained therein, and to erect or lease such areas of land or water, buildings, boats or other structures, as in their opinion may be necessary for the proper pursuit of the above objects. Said commissioners may expend for the purposes of this resolve a sum not exceeding fifteen hundred dollars a year for a period of three years.

CHAPTER I. — INTRODUCTION.

Dr. GEORGE W. FIELD, *Chairman, Massachusetts Commission on Fisheries and Game, State House, Boston, Mass.*

SIR: — I herewith submit the following report upon the life history and habits of the scallop (*Pecten irradians*). All investigations herein were made in accordance with the provisions of chapter 74, Resolves of 1906. The work was conducted by D. L. Belding, assisted by W. G. Vinal in 1907, 1908 and 1909, and by W. H. Gates and C. L. Savery in 1906.

Respectfully submitted,

DAVID L. BELDING, *Biologist.*

The following report embodies the results of the experiments and investigations conducted on the Massachusetts coast during the years 1905 to 1909. The facts discussed in this paper are intended for the inspection of three classes of readers: the fisherman, the consumer, and the scientific student, each accustomed to the daily use of terms with which neither of the others is familiar. This circumstance, added to the

fact that the subject-matter of the report is largely technical in character, renders it doubly hard to present the material in clear and comprehensive form. As the investigations were primarily designed for the benefit of the fisherman, the terms as far as possible will be those used by the practical seacoast inhabitants, while the report is arranged so that sections which are purely scientific may be omitted without impairing the value of the whole paper. Whenever a scientific or colloquial name is used in the text the common name is either given with it or a more complete definition is appended in the glossary.

The circumstances which led to the legislative act authorizing the investigation were briefly as follows: In the years previous to 1905 the scallop industry, while still an important source of winter revenue for the southern coast towns of Massachusetts, manifested signs of serious decline, especially in the Buzzard's Bay region. A natural resource of sufficient importance to bring into the Commonwealth a yearly revenue of nearly \$150,000 could not be neglected, and the result was that the Legislature directed the Department of Fisheries and Game to study methods of improving the scallop fishery. The laws which were at that time in force were based on very defective knowledge of the life history and habits of the scallop, and it early became apparent that a knowledge of these important points was essential for proper legislation for the conservation of the industry. It is earnestly hoped that an immediate result of this investigation will be the passage of suitable legislation for the preservation of the scallop fishery.

Object. — The aim of this report is to publish all known facts about the life and habits of the scallop, and to show their proper bearing upon the present fishery. At the beginning of the investigation certain important questions of a practical nature presented themselves.

(1) Is the scallop supply of Massachusetts in danger of extermination? If so, how can this be avoided?

(2) Is the present protective legislation based on accurate knowledge of the life and habits of the scallop?

(3) Can the scallop be propagated artificially?

(4) How can the present industry be increased?

In order to obtain satisfactory answers to these questions it was found necessary to obtain information upon: —

(1) The distribution and range of the scallop.

(2) The anatomy and its relation to the habits of the animal.

(3) The spawning, reproduction, early life history and propagation.

(4) The habits of the young and of the adult.

(5) The rate of growth and length of life.

(6) The scallop fishery, — its present extent and possibilities.

Presentation. — Information on the above points, as completely as possible, is presented in the following pages, each topic in the form of a chapter; and the practical bearing on the four questions is considered whenever feasible under each subject, and is summarized in the

general conclusion at the end of chapter VI. It is realized that there are various facts which still require further study, and that it will take years of investigation to complete the history of the animal. The anatomical description in chapter II. is by no means complete. The object is merely to give the reader a general idea of the structure of the animal, and to make clear the more intricate development of the various organs as they appear in chapter III. No claim is made for marked originality or for detailed work in the chapter on anatomy; the general scheme given by Drew (1) is closely followed, and only a simplified description is given. Likewise, the embryology of all the lamellibranch mollusks have such a close similarity, not alone in the general course of development, but even extending in some cases to very minute details, that the description of any species might be applied equally well during its early stages to any other closely related species. Thus, although our work upon *Pecten irradians* was begun four years ago, and carried on entirely independently, and is, we believe, the only work upon this species which even professes to approximate completeness, its general features closely parallel the admirable work of Drew (1) upon *Pecten tenuicostatus* (the deep-sea scallop). Many of our results, therefore, are entirely new for *Pecten irradians*, and, since they confirm the earlier published observations on this and other species by Drew (1), Jackson (4) and others, to whom due credit is given, are of use not alone as confirmatory evidence; but since they contribute new observations and original applications of these facts to the practical solution of how best to develop and maintain our scallop fishery we trust that they are not without value. The life history is given in narrative form and is not explained in detail, as could be done by sectioning the developing eggs and embryos. As it is the purpose of this paper to present not only new material but also a rather complete account of the life and habits of the scallop, it has been frequently necessary to reprint or refer to previous works on the subject. In most cases these observations have been verified by our experiments, and are printed with the consent of the authors.

Courtesies. — At the start of the investigation in 1906 there was found a general lack of knowledge among the fishermen upon such important points as the spawning season, rate of growth and length of life of the scallops (*Pecten irradians*). Indeed, little literature on the subject was available, Kellogg (5), Jackson (4), Ingersoll (8) and Risser (2) comprising all publications on *Pecten irradians*. Of these, Risser alone dealt with the spawning, growth and length of life in his report upon the life history and habits of the scallops in Narragansett Bay, Jackson with the young scallop, and Kellogg and Ingersoll with the industries. While the paper by Risser was of great assistance at the start of the work, the diverse natural conditions in Massachusetts waters often rendered our results at variance, and unfortunately made this excellent

report only valuable for comparative purposes. In addition to these publications the following papers proved of special value in the work: Drew (1) was of great assistance in studying the embryology and in preparing the chapter on anatomy; Jackson (4) furnished considerable help and useful methods in tracing the post-embryonic development; and Kellogg (6) was found a most comprehensive and valuable paper for general reference work.

The writer is deeply indebted to Dr. George W. Field for his general supervision and helpful advice in the investigations and in the preparation of the report; to Prof. James L. Kellogg of Williams College, and Prof. Gilman A. Drew of Maine University for their kindly criticism; and to the scallop fishermen of Massachusetts for their friendly assistance. More especially is acknowledgment due to the assistants in the investigation. In the summer of 1906 W. H. Gates and C. L. Savery ably assisted in the post-embryological investigations and general growth experiments. During the summers of 1907, 1908 and 1909 W. G. Vinal, together with D. L. Belding, brought the embryological and post-embryological work to a completion. The work of all three assistants, particularly the continued investigations by W. G. Vinal, is worthy of special commendation.

Methods of Investigation. — The greater part of the work on the scallop was conducted at Monomoy Point in the town of Chatham. Near the end of this point an enclosed body of water, some 6 acres in area, connected with the ocean by a shifting channel through which the tide passed every twelve hours, was acquired by the State for experimental purposes. This body of water, called the Powder Hole, is a natural breeding ground for shellfish, and proved an excellent place to study their life history and habits. A few scallops were found in the Powder Hole at the beginning of the investigations; more adults were brought there for breeding purposes and the basin was transformed into a natural aquarium. In this way it was possible to keep close observation on several successive generations of scallops in regard to their growth and length of life under completely natural conditions. A small laboratory was erected on the shore, and a raft 20 feet long by 10 feet wide was securely moored in the deepest part of the cove. The raft proved an invaluable aid in catching and rearing the young, some of the most important experiments being conducted on it.

While Monomoy was the central station for the scallop work, observations were made in other parts of the State under as diverse conditions as possible. Records of the spawning, growth, migration and habits were kept at Edgartown, Nantucket, Chatham, North Falmouth, Marion and Monument Beach. In this manner the entire scalloping territory of the Commonwealth was under surveillance. Under chapter VII. the specific methods of work will be given in greater detail.

The Scallop Family. — The scallop belongs to the class of mollusks

called the *Lamellibranchia*, or, to use an older nomenclature, the *Pelecypoda*. The family of the *Pectenidae* includes a great many species, totalling about forty, of which the most important commercially is the shallow-water variety, *Pecten irradians*. Of the four species found on the Atlantic coast only two are of commercial importance in New England, *Pecten irradians* and *Pecten tenuicostatus*, the giant or deep-sea scallop of Maine. These are rivals in the Boston market, but the smaller scallop is usually preferred by reason of its more delicate flavor. Several different species of the *Pectenidae* are used as food in other countries. Fossil *Pectens* have been found as far back as the Carboniferous age.

Names. — *Pecten irradians* is more commonly given as the scientific name for the shallow-water scallop of the Massachusetts coast, but the later and more exact title of *Pecten gibbus*, var. *borealis* Say., is now used. In New England the animal is ordinarily called by the name "scallop," sometimes written "escallop." This word, according to Ingersoll (8), is derived from either the French "escalope" or the Dutch "schelp," meaning a shell. In Italy the scallop is called "cape saute," in Holland "mantels," in England "fan shells," "frills," "queens," and "squims."

Distribution. — *Pecten irradians* has a wide geographical range, extending from Massachusetts Bay to the Gulf of Mexico, where it has been reported in the vicinity of the Chandeleur Islands in Louisiana by Professor Kellogg (7). It is occasionally found along the Atlantic seacoast wherever the coast is sufficiently broken to afford sheltered bays and inlets. In 1880 Ingersoll (8) reports its presence in North Carolina, where it was used for local trade at Moorehead City. The scallop inhabits quiet waters, where it is protected from heavy winds and storms, which would wash it high on the sandy beaches. Long Island Sound is very productive of scallops, and many thousands of gallons are shipped from its waters in a successful season.

In Massachusetts this species occurs commercially only in the waters south of Boston (Fig. 78). It is usually found in abundance along the southern shore of Cape Cod, in Buzzard's Bay and about the islands of Nantucket and Martha's Vineyard. According to a map in the Boston Museum of Natural History a small bed formerly existed in the waters off Nahant. Shells are often picked up on the North Shore beaches, but at present no live scallops are found in this State north of Boston. It is reported that a few are to be found in some of the warm bays of the Maine coast. Thus the scallop fishery in Massachusetts is only a partial industry, as it concerns only the Vineyard Sound and Buzzard's Bay shore.

The bathymetrical range of the scallop is extensive, as many thousand acres of eel-grass flats, extending even to a depth of 60 feet of water, are covered at times with this bivalve. Usually the scallop is found in

water from 5 to 30 feet deep. Scallops are often abundant on the high flats where there remains but a foot or two of water at low tide, as on the Common Flats at Chatham. These exposed places with the thick eel grass seem to receive the heaviest sets, but the young often perish in the cold winters. Scallops can arbitrarily be separated into two classes: (1) the channel or deep-water scallops, found in water 15 to 60 feet deep, and (2) the shallow-water or eel-grass variety, from low-water mark to 15 feet.

While the extent of the scalloping area is large, owing to the wide range of the animal, only portions are ever productive at any one time. A set may be in one place this year and the next year's spawn may "catch" in a different locality. Thus, while all the ground is suitable for scallops, only a small part is in productive operation each year. The natural barrier to the distribution of the scallop is the exposed nature of the coast, as this mollusk cannot live in rough waters.

CHAPTER II. — ANATOMY.

The loss of the anterior adductor muscle in *Pecten*, as shown by Drew (1) and Jackson (4), has been accompanied by a shifting of the soft parts, so that the antero-posterior axis, instead of running parallel to the hinge line, forms with it an angle of at least 60°. While this fact is recognized, for simplicity the relation of the hard and soft parts in the following description is considered as in a typical lamellibranch. The animal is oriented: (1) dorso-ventral axis or height, from the hinge to the opposite edge of the shell; (2) antero-posterior axis or width, the distance across the shell; (3) lateral axis or thickness, the distance between the two valves (Fig. 65).

The Shell. — The scallop shell consists of two lateral valves joined together on the dorsal edge, the hinge line (HH), by means of a thin ligament. The two valves, which open on the ventral or lower edge, are nearly round and of equal curvature. The right or lower valve, on which the animal rests, is of a lighter and cleaner color and differs from the upper in having a byssal notch (B) or foot groove. In the scallop less than a year old this notch is lined with several projecting teeth, which are absent in the old animal. If the shell of an adult is broken along the notch a row of thirty-five or more of these teeth can be seen extending back to the umbo. The adult scallop is somewhat wider than high, the average dimensions being: height, 2 $\frac{3}{10}$ inches; width, 2 $\frac{3}{10}$ inches; thickness, 1 $\frac{1}{10}$ inches.

On the outer surface of the shell are prominent ridges and furrows (R, F) which radiate from the beak to the free margin, giving the animal a beautiful fan-like appearance. The number of ridges does not vary in the individual scallop, the adult having the same number as the very young animal. In different scallops the number of ridges

varies from 14 to 19, the average being 16. Crossing the radiating ribs are concentric growth lines, which almost show the daily accretion of the shell. Age and wear cause these to be less conspicuous toward the beak and on the lower valve. During the winter months growth ceases and when again resumed in the spring, a heavy line has formed by the thickening of the edge of the shell, comparable to the annual ring of a tree. This is the so-called growth line, which defines a "seed" or immature scallop. Such marks may not always represent the end of the season's growth, but may indicate that unfavorable conditions for a certain length of time checked the building processes of the animal. When scallops were transplanted from Inward Point to Monomoy Point, being confined several days, the change caused a mark similar to the annual growth line.

In old age these growth lines may pile up and form a very slight re-entrant in the shell, due to retrogressive development. The re-entrant is not so conspicuous in *Pecten* as in other lamellibranchs which have a thicker shell. If the edge of one valve is broken, the opposite valve grows down abnormally to protect the soft parts. Both valves are needed in place to get a normal growth in the same manner as rodents require both sets of incisors to wear on each other.

Besides these markings the outer surface of the shell may be engraved by various enemies. The oyster drill often punctures a small hole in the shell and through it sucks out the soft parts. The boring sponge does not attack the scallop as frequently as it does the oyster and other mollusks which lead a sedentary life, but occasionally parts of the shell are dissolved by the secretions of the sponge. In the older scallop of fifteen months the upper valve is usually covered with various forms of life, such as *Serpula* (worm tubes), barnacles, young oysters, *Anomia* (silver shells), *Crepidula* (quarter deckers), *Acmaea* and such sea weeds as *Enteromorpha*, *Ulva* and *Champi parvia*. Many old scallops are doubtless killed by the accumulation of foreign growth, which at times fastens the valves together.

The inner surface of the shell is very smooth and somewhat vitreous, due to the nacreous or pearly material secreted by the mantle. The ridges and furrows exist but are not conspicuous. The scar, which marks the attachment of the adductor muscle, can be seen indistinctly outlined slightly to one side of the center of the shell.

The hinge line (HH) is curved in most lamellibranchs, but in *Pecten* it is straight, and extends to the end of the well-developed "ears." A V-shaped spring in the central part of the hinge tends to keep the valves apart after the same manner of doubling a large piece of rubber in the hinge of a door. When the animal is at rest the large adductor muscle is relaxed and the valves remain open.

The calcareous shell is formed by the secretions of the mantle. Although it is added to slightly by the surface of the mantle, the main increase is in height and width at the edge of the mantle. These two

secretions differ in structure; the inner pearly or nacreous portion being formed of thin layers, the outer of prisms. The valves increase in size as the direct consequence of the increase in size of the soft parts.

The shell is well adapted to the life of the scallop. Being light in weight it is suitable for movement through the water, while the rounded outline is the form which offers the least resistance for swimming. The opposite ridges and furrows fit tightly together when the valves close. Thus, when the animal moves, streams of water are forced by the aid of the mantle through the small openings below the "ears," or from the ventral edge of the shell.

The Mantle.—The shell of the scallop is lined with a thin ciliated organ called the mantle (Fig. 73, m). The thickened margins of the two mantle lobes are free ventrally but are united dorsally and to a slight extent on the anterior and posterior ends in the region of the "ears." In a scallop of 52 millimeters the mantle lobes are united posteriorly for 13 millimeters and anteriorly for 6 millimeters. This corresponds roughly to the width of the "ears" of the shell, 12 millimeters and 6 millimeters respectively. The shorter union anteriorly permits the extrusion of the foot. The free edge of the mantle, often brightly pigmented, possesses tentacles (t) or tactile organs, and bead-like eyes of a bright blue color. These sensory organs are not so numerous or so large near the byssal notch and the corresponding posterior edge. Each lobe of the mantle is attached to the inner surface of the valve about one-half inch from the free edge. The broad face of each lobe rests on the inner surface of the shell except when the animal is disturbed and the mantle withdrawn by the retractor muscles. While resting, the mantle lobes are held slightly apart, the guard tentacles forming a lattice work between the perpendicular flaps of the mantle through which the water passes. As previously stated, the mantle also functions in the formation of the shell.

Tentacles.—The sense organs of the mantle are of two kinds, tentacles and eyes. There are numerous tentacles near the free edge of the mantle, which vary greatly in size and formation. These tentacles can be divided into two classes, (1) the mantle tentacles, which are situated on the external edge of the lobe in several rows, and (2) the guard tentacles, situated on the edge of the perpendicular flap of the mantle, 5 to 6 millimeters from the edge. Each class differs in form and function; the mantle tentacles are larger, capable of greater extension and contraction, and armed with papillary projections, while the guard tentacles are smaller, less extensible and of a bright color. The tentacles have a sensory or tactile function, and when the scallop lies undisturbed, the mantle tentacles, lengthening out, wave slowly in the currents of water. They can be withdrawn immediately at the passing of a shadow or at any slight disturbance in the water. When contracted each forms a slight conical projection.

Eyes.—Situated between the band of tentacles and the outer edge

of the mantle are many well-developed eyes, brilliantly hued with blue and brown pigment, which help to make the scallop attractive to summer colonists. When sectioned, these eyes are found to be specialized organs comparable to the eyes in the higher animals. They vary in size and number, the larger ones usually occupying the grooves of the shell, although in the adult definite arrangement appears to be lacking. To what degree the eyes react to light and to external stimuli is problematic, and offers a field for research. They appear to be keenly sensitive to any change in light and shade, possibly observing the approach of an enemy by its shadow or movement in the water.

Muscles. — Unlike the soft clam (*Mya*) and the quahaug (*Venus*), which have two adductor muscles for closing the shell, the scallop has only a single adductor muscle (the so-called eye in the fisherman's vernacular), which is situated posterior to the center of the shell, forming a conspicuous part of the internal anatomy. The muscle is made up of two parts, a large anterior section and a small posterior division. As is shown in the development of the young scallop, this muscle is the posterior, the anterior adductor disappearing during the early shell stage. The muscle is the edible part of the scallop, and its shape is maintained when served on the table as "fried scallops." When the muscle is cut the valves immediately gape open, being forced apart by the V-shaped cartilaginous elastic pad in the middle of the hinge. The other important muscles are the retractor muscles of the foot, the gills and the mantle.

Gills. — There are four gills (Fig. 74, g) in the scallop, a pair on each side of the generative mass and ventral to the adductor muscle. Each pair has a free end posteriorly and extends in a curved line nearly around the posterior adductor muscle. The gills are attached dorsally near the adductor, the inner and outer gills having a common membrane. Each gill is made up of two lamellæ of radiating filaments. Fine markings cross the filaments at right angles, thus giving each lamella a delicate lace-like appearance.

When a few grains of carmine powder are sprinkled on the gills the small grains pass to the base of the gills and then move toward the anterior end in a definite channel. This movement is due to the cilia between the filaments, which cause the grains to pass toward the mouth. The work of the gills is not only to strain out the food but to aid in respiration. The impure blood flows into the capillary spaces of the gills, where the delicate membranes are bathed by the inflowing water, and, having acquired a new supply of oxygen, passes back to the heart. The area is increased by the folding of the lamella. If stimulated, the gills contract immediately, showing that they possess a nervous mechanism.

Palps. — Just dorsal to the gills on the borders of the mouth are two pairs of delicate filaments similar in structure to the gills. These

organs are the labial palps (lp), which correspond to the lips of higher animals and function in conducting the food to the mouth. The central portion of these lips, which extend laterally for a distance equal to the thickness of the animal near the umbo, has arbor-vitæ-like processes, concealing the mouth. The flaps which extend on each side of the branching area are united to the body dorsally and posteriorly, leaving the other edges free. The exterior surface is smooth, while the internal surface is covered with ciliated ridges and furrows which aid in conducting the food from the gills to the mouth.

Digestive System. — The digestive system of the scallop is comparatively simple. The mouth opens into a short cesophagus or gullet, which leads into a gourd-shaped stomach (s). On the posterior end of the stomach is a curious hard socket into which fits the tip of a translucent gelatinous rod, the crystalline style. This rod extends along the intestine in a sort of pocket or groove as far as the lower part of the visceral mass (Fig. 75, vm). The stomach is enveloped by a dark-brown mass, connected with it by two short canals, one on each side. This large conspicuous organ is the digestive gland or "liver" (1), and "is only bounded in the region of the stomach by the sexual gland on its ventral surface." Kellogg (6). The liver (1) sends secretions into the stomach to aid digestion. The food is caught up as soon as it leaves the stomach by the cilia of the intestine (i), which forms a double loop in the visceral mass (Fig. 76, vm). It then passes in a dorsal direction through the liver, curving posteriorly to pass through the heart, and finally ends posterior to the ventral portion of the adductor muscle.

Circulatory System. — The scallop has a blood system passing over the whole body and through the gill filaments, where the blood is aerated. The heart (ht), a three-chambered organ, is situated in a pericardial cavity dorsal to the adductor muscle. The intestine passes through the pericardium and is surrounded by the ventricle of the heart. The auricles are two filmy bodies connected with the ventricle. From the heart arise the different arteries which conduct the blood to all parts of the body, whence it is returned through the venous system to the sinus venosus, from there to the gills, and finally back to the heart.

Nervous System. — The nervous system of the scallop is complicated, and the animal is highly sensitive in all parts, especially in the region of the mantle, through the circumference of which passes a large nerve connecting with the tentacles and eyes. Several ganglia lie in the region of the mouth, foot and visceral mass. From these, numerous nerves pass to the various parts of the body.

Excretory System. — The kidneys are a pair of yellow-colored organs in the form of sacs, encircling the anterior part of the adductor muscle. These glandular organs open into the mantle chamber above the gills, where they are joined by the openings of the reproductive organs.

Foot.—The foot (f) of the adult scallop is a small muscular organ extending from the upper part of the visceral mass dorsally for about a quarter of an inch. It is nearly cylindrical, with a deep groove on one side and a hollow, sucker-like disc on its distal end (Fig. 42). It has a slight twist which places the cleft portion in juxtaposition to the right valve, instead of on the ventral border. This is of use to the young in crawling, as the sucker can be put down evenly on the surface without a twist of the foot to hinder the retraction. Jackson (4). The function of crawling is only for the young, and the adult has either lost the power of locomotion through degeneration or at least does not make use of it. A byssal gland (bg) is on the proximal end of the foot, and secretes the bundle of threads by which the mollusk anchors itself to various objects, as described under "Attachment" in chapter IV.

The Reproductive Organs.—The generative organs comprise a large share of the soft parts of the scallop, and lie, surrounding the folds of the intestine, in the lower portion of the visceral mass. The surface of this mass, which terminates bluntly some distance below the large adductor muscle, is usually covered with a black glossy pigment, which is especially noticeable previous to and during the spawning season, when it completely hides the bright color of the egg sac. Both the male and the female organs are found in the same scallop, whereas in *P. tenuicostatus*, the giant scallop of the Maine coast, the sexes are separate. Drew (1).

The testis (Fig. 75, ts) or male gland is a cream-colored organ lying just ventral to the liver and foot and extending down the side of an orange-colored sac. This sac is the ovary (ov) or female gland, which during the spawning season takes on a bright orange color, presumably due to the number and ripeness of the eggs. In size it is somewhat larger than the testis, and lies ventral and slightly posterior to that organ. During the early part of the spawning season, when full of eggs and spermatozoa, these glands are well rounded and brilliantly hued; but after the completion of spawning they become small and lighter colored. In the ovary of the scallop previous to spawning are many millions of little eggs in various stages of maturity. These eggs, held in large follicles, are packed firmly in place, giving to the generative mass a smooth, plump appearance. Dr. James L. Kellogg has kindly permitted the use of an illustration from his work on the "Morphology of Lamellibranchiate Mollusks, 1890," which shows a section of the generative organs of *Pecten irradians*, and supplements it with the following excellent description:—

Fig. 67 represents a section passing vertically through the outer wall of the visceral mass, where the testis and ovary are closely apposed. The body wall is represented at ep and consists of a single layer of columnar, ciliated, epithelial cells, whose nuclei are about equally distant from their outer ends and the thick basement membrane (bm). In this epithelium are

many conspicuous gland cells (glc). Between it and the follicles of the generative gland is a thick layer of connective tissue, extending in between the follicles. The follicles of the ovary (ov) are not so regular in outline when seen in section as those of the testis (t). The walls of the latter bear a follicular epithelium (fep). In the ovary, the cells of this layer are in all stages of development into eggs. The eggs themselves, crowding the follicles, possess a very thick membrane and their protoplasm is finely granular. A duct from the follicles is seen at d.

The mother cells of the spermatozoa (fep) are circular and of constant size in the follicles of the testis (t). As we follow the mass of cells inward from these mother cells they become very gradually smaller and smaller, until their final divisions result in the spermatozoa. They are so arranged that their "tails," in forming, project in extended masses toward the lumen of the follicle and give it a radiating appearance. I have not been able to determine how many times a mother cell divides in forming spermatozoa, for the cells are all rounded and give no evidence of their divisions, as they do in the testes of many animals. A duct of the testis containing spermatozoa is shown at d. The ducts of both testis and ovary are composed of slightly columnar, ciliated cells. In the wall of the duct of the testis is shown a single deeply stained cell, which is evidently a gland cell.

CHAPTER III. — EARLY LIFE HISTORY.

The Ripening of the Reproductive Organs. — In the early spring the sex products of the scallop begin to ripen, as the eggs and spermatozoa mature preparatory to the summer spawning. The final ripening takes place during the month of May, when the water has reached a temperature ranging from 45° to 50° F., and the scallop is prepared "to shoot its spawn" in the first part of June. During the month of May the generative organs take on a plump appearance; the eggs grow larger; the spermatozoa become active; and the ovary passes from an indiscernible pink to a deep orange color. This change in color furnishes a general index for recording, by the aid of color charts, the spawning period of the scallop.

The Egg. — The egg or female cell (Fig. 1) is a small spherical body surrounded by a thin membrane inclosing a protoplasmic fluid. Lying in the protoplasm are numerous yolk granules which give to the egg an opaque appearance. These granules form the nutritive part of the egg. The shape of the mature egg when extruded appears spherical, but, when measured, one axis will be found slightly longer than the other. If the eggs are cut from the ovary they have a variety of shapes, due to the manner in which they were compressed within that organ (Fig. 3). The scallop egg resembles that of the clam and oyster in size, the average diameter being about $\frac{1}{400}$ of an inch. In the ovary the eggs, when mature, have an orange color, and when discharged "en masse" still retain that color; but when separated appear to the naked eye as minute white specks. The color intensity of the mass seems to be due to

the arrangement of the yolk granules within the egg. A light color appears to be caused by large vacuoles or clear spaces among the yolk granules, as are often found in distorted and immature eggs. Evidently the number, size and arrangement of these vacuoles in respect to the granules determine the color of the mass, and thus indicate the maturity or immaturity of the eggs. Orange-colored ovaries when placed in 75 per cent. alcohol in a short time become white, the orange color being extracted by the fluid.

The Spermatozöon.—The spermatozöon or male cell (Fig. 2) is extremely minute, being only an exceedingly small fraction of the size of the egg. It consists fundamentally of two parts, an elliptical head and a slender whip-like tail, which is used as an organ of locomotion in seeking the egg. The size of the head is $\frac{1}{280}$ by $\frac{1}{600}$ of a millimeter ($\frac{1}{6500}$ by $\frac{1}{12500}$ of an inch), with a tail about $\frac{1}{20}$ of a millimeter ($\frac{1}{600}$ of an inch) in length. The minute anatomy was not studied.

Spawning.—The term "spawning" refers to the discharge of the eggs from the female or the spermatozoa from the male. With most of the lamellibranchiate mollusks, the class to which the scallop belongs, it is the act of throwing off the sex products, which meet in the water for the purpose of fertilization. *Pecten irradians*, as is often the case with highly specialized mollusks, is hermaphroditic, *i.e.*, both sex elements are found in the same individual. Spawning in this instance is the discharge of either eggs or spermatozoa from the same animal, usually at different times.

In the Pectinidæ the opening from both ovary and testis lead into a common duct with a single orifice, which opens into the kidney comparatively near its external aperture. Pelseener (9). The sexual products, as they are extruded, pass through a part of the kidneys just dorsal to the large adductor muscle into the mantle chamber, where they are discharged into the water. The discharge takes place through the pseudo-siphon, formed by the mantle when closed, at the right or posterior edge of the shell, as the animal lies in a natural position. The spawn is usually cast forth as a fine spray by a quick snap of the valves and is rapidly diffused through the water, though sometimes the valves remain quiet, the spawn then passing out in a steady stream. As the mantle fringe is slightly opened to allow the spawn to roll gently out, this latter method can be compared to the exhaling of tobacco smoke from the human lips. If eggs are given off they either appear in pink masses or are just visible to the naked eye as fine white specks, making it possible for the observer to readily distinguish them from the spermatozoa, which give to the water a quivering, milky appearance. The amount of eggs extruded at one time varies considerably, but generally numbers high in the thousands and even millions.

The following observations upon the spawning of individual scallops were made at Monomoy Point. The scallops were confined, as described

in chapter VII., in small aquaria during the period of observation, and were replaced in their native element between times. Possible error arises from the unnatural conditions, which may render the spawning abnormal. Unfortunately no satisfactory method of eliminating this error could be devised. These observations, however, have been partially confirmed in other ways.

(1) *When the scallop spawns, which sex cell is liberated first?*

Observations on 38 scallops showed that 19 produced spermatozoa, 17 eggs, and 2 a mixture of both at the first discharge. In general, the scallop continues shooting for a number of discharges the kind of sex cell with which it starts, and although scallops are hermaphroditic, only a single kind is usually given off at any one time, the length of the period varying from a few minutes to five or six hours. It can be safely concluded that it is purely a matter of chance which sex cell is given off, and that the tendency toward one kind may be a precaution against self-fertilization.

(2) *How long are the intervals between discharges?*

The intervals between discharges vary from one-half a minute to forty-five minutes, or even days. After a series of rapid discharges the resting period appears to be longer. One scallop was observed to give as many as five successive discharges, while two are of frequent occurrence. Other specimens have been observed to shoot spawn at intervals of two or three minutes for over five hours. The scallop possibly can adapt itself to existing conditions and spawn only at favorable times. If the germ cells are set free at intervening periods over a long space of time there is a greater chance of surviving.

(3) *Do scallops throw all their spawn in one day?*

Numbered scallops were placed in separate aquaria for periods of two hours for several days, a record being kept of the spawning of each individual. After each test the animals were suspended in wire baskets from a raft at a depth of 10 feet in water, which was considerably cooler than the sun-warmed water in the aquaria, probably preventing further shooting of spawn. Although only 25 per cent. threw spawn we can infer that scallops shoot their sex products little by little, as the same individuals were found to give forth spawn after an interval of several days. This fact indicates that the spawning season for one scallop probably extends over a period of days and even weeks. Records with color charts, upon scallops of another set, likewise show that spawning is gradual.

(4) *Do scallops spawn at any particular time of day?*

Scallops have been observed to spawn as early as 8.15 A.M. (July 13, 1907) and as late as 4.30 P.M. (July 12, 1909), and at various times between these hours. Although sunlight is more favorable, the scallop will spawn on cloudy days and probably at night, as the time of spawning is largely determined by the temperature.

(5) *What temperature is most favorable for spawning?*

In confinement scallops have been observed to throw spawn at all temperatures from 68° to 84° F., although above 76° F. was most favorable. Great variation is found, as every scallop is a distinct individual and the eggs vary in degree of maturity. One scallop gave off its sex elements at a temperature of 68° F. in fifteen minutes after being placed in the aquarium, while at 78° F. one spawned in three minutes and others took hours. Under natural conditions the spawning season begins when the water reaches 61½° F. As a rule high temperatures are most conducive for spawning.

(6) *At what age does a scallop first spawn?*

The extreme rapidity of growth makes it possible for the scallop to spawn when exactly one year old. With the clam, spawning occasionally occurs at the age of one year, with the quahaug only in very exceptional cases, but with the scallop the most important reproductive period, and the only one of practical value, comes at this early age. This fact is explained by the short life of the scallop, from twenty to twenty-six months, as compared with the many years of the clam and quahaug.

(7) *Is there a second spawning season?*

For the majority of scallops there is only one spawning season. Nature has so regulated that less than 25 per cent. attain a length of life of two years. In the few scallops which pass the two-year mark, eggs and spermatozoa apparently develop normally, and if the animal lives through the season it produces offspring for the second time in its life. These two-year-old scallops are larger, and the ovaries and testes are of correspondingly greater size. Two-year-old scallops are occasionally found in small beds, but large numbers are by no means of common occurrence. In the protected waters of the Powder Hole two-year-old specimens were frequently found. During the summer of 1909 a comparatively large number of the set of 1907 were found. This set was peculiar for its slow growth and small size, the two-year-old animals being about the size of normal one-year-old scallops. The spawning of this set was perfectly normal during the second season, and the sex products could in no way be distinguished from those of yearlings. Although it is possible for scallops to spawn a second time, provided they pass the two-year limit, their economic importance is slight, owing to the small per cent. which survive so long. The first spawning season must, therefore, be considered the only practical one in legislation for the welfare of the scallop fishery.

This fact proves that all scallops under *one year old must be protected*, as these furnish practically all the spawn for the following year. Only scallops under this age *need* protection. If the scallop under this age is amply protected, the law has done all in its power to insure the future of this profitable industry. It does no harm to capture scallops *over* one year old; in fact, it would result in economic loss if

they were not taken, as nearly all die from natural causes before a second season.

The Spawning Season.—In Massachusetts waters, owing to the diversity of conditions as regards locality, environment and seasonal changes, it is difficult to define the spawning season exactly and only general limits can be given when the entire territory is considered. As a rule, temperature seems to be the controlling factor, as is demonstrated by the variation of the season according to locality and years. The entire period roughly covers two months, averaging from the middle of June to the middle of August (Fig. 83). The height of the spawning occurs during the first weeks in July, and although the season drags on for a month longer, the greater part of the mature eggs have been liberated. Different localities, with the same general limits, often vary in having the height of the spawning at different times. While the spawning of the scallop as a class extends for two months, the duration of the season for the individual runs anywhere from one day to several weeks.

(a) *Spawning Season at Monomoy Point.*—During the summers of 1906 and 1907 the spawning season of the scallop was followed in the waters of the Powder Hole at Monomoy Point, and supplementary observations were made during 1908 and 1909. During the first two years conditions in this locality were practically the same, thus eliminating nearly all variation factors except seasonal change. It is, therefore, fair to assume that the following variations are mostly due to the difference in the temperature of the two years.

In comparing the two years 1906 and 1907 the following points will be considered: (1) date of first spawning; (2) length of time spawn could be obtained for successful artificial fertilization; (3) date of appearance of the set on raft spat collectors.

(1) Careful observations were made in regard to the beginning of the spawning season, and the start was accurately determined for this locality. In 1906 scallops first extruded eggs and spermatozoa on June 12, and in 1907 on June 21, a variation of nine days. The average temperature of the water on June 12, 1906, was 61.5° F., on June 21, 1907, 61.5° F. June 4, 1906, was equivalent to June 18, 1907, in regard to the temperature, which reached 60° for the first time on these dates, showing that the seasonal variation in temperature was about two weeks. In both cases there had been a previous rise in temperature. By June 20 this difference had vanished and the daily temperatures for the two years were approximately the same (Fig. 81).

(2) For successful artificial fertilization spawn could be obtained for both years as late as July 20. Mature eggs and active spermatozoa were found in the reproductive organs later, but the scallops did not give forth spawn readily after this date. The records made with the color chart show that the spawning season is not complete before the middle of August.

(3) Very little variation was found in the sets of 1906 and 1907 on the raft spat collectors, but the 1908 and 1909 sets were slightly earlier, though fewer in number. The temperature of the water at the time of set was about 70° F. In 1906 the set began July 26 and reached its height August 4; in 1907, July 24 and August 2; in 1908, July 18 and July 26; in 1909, July 22 and July 29, respectively.

In the above cases, more especially the first, temperature seems to be the controlling factor. The warmth of the water determines an early or late spawning season, as is shown by the difference in the start of the seasons of 1906 and 1907, the latter being nine days behind the former. In each case spawning did not start until the water had assumed a temperature of 61.5° and had been over 60° for a few days. Spawning does not take place until the temperature of the water is sufficiently high to enable the young larvæ to live. Thus, in comparing the two years we find that the variation in the spawning compares in every detail with the variations in temperature, and, when other factors are eliminated, depends directly upon it. The average summer temperature controls the length and completeness of the spawning season, as is directly manifested by the time and amount of set.

(b) *Conditions influencing the Spawning Season.*— In any given area the spawning depends on the latitude and on the climate, temperature again being an important factor. In Rhode Island, in the warmer waters of Narragansett Bay, the season lasts from June 1 to July 1, reaching its height about June 15, Risser (2), as compared with June 15 to August 15 in Massachusetts waters. Naturally the farther south the earlier the season, as the warmer waters hasten the spawning.

While the temperature is the main factor in determining the spawning, it is by no means the only one. The natural conditions of any locality, such as its suitability for growth, for food, depth of water, kind of bottom, enemies, exposure, and other factors which make up the environment of the scallop, play their part in determining the spawning season. Scallops in shallow water spawn slightly earlier than those in the deep, probably due to difference in temperature, while those under favorable growing conditions probably spawn in advance of scallops less favorably situated.

(c) *Length of Season in Massachusetts Waters.*— The different localities present considerable variation not only within their borders but with each other. The four sections of the scalloping territory given in chapter VI. are useful for a comparison of the spawning season, owing to their divergent conditions. The work of determining the spawning season, as described in chapter VII., was conducted during 1905 and 1906 by (a) general observations of the ovary; (b) color chart records; (c) appearance of set.

(1) On the north side of Cape Cod conditions are not favorable for scallops and there is but a small industry. In Cape Cod Bay the water

is colder than south of the Cape, and the spawning would naturally be somewhat later. In the harbors, such as Wellfleet Bay, the reverse is true, as the broad exposure of flats, heated by the sun, gives a greater warmth to the water. In these cases many scallops are left in little tide pools, where they bask in the sun and shoot spawn in these small natural aquaria. The eggs have thus a chance to develop in quietude until the incoming of the tide, when the little embryos join company with the young from the other pools and begin the keen competition of life. The spawning season lasts from June 25 to August 15.

(2) On the south side of Cape Cod is found a great variety of territory and conditions, which nearly approximate those of Monomoy Point. The limits of the season in this locality are from June 15 to August 15.

(3) The conditions at Nantucket and Edgartown closely approximate those on the south side of Cape Cod, and except for local variations the spawning season is the same.

(4) In the warmer waters of Buzzard's Bay spawning is somewhat earlier, the set usually being about two weeks in advance of Monomoy. The limits of the season scarcely differ from the south side of Cape Cod and the Islands, but the main part of the spawning takes place earlier. The season lasts from June 1 to August 1. The Buzzard's Bay scallop is larger in size than the scallop in the other localities, owing to earlier spawning and rapid growth.

Fecundation. — Fecundation is the union of the female cell (egg) with the male cell (spermatozoön), which results in the formation of a new individual that partakes of the nature of both parents. Since the eggs of the scallop are fertilized externally, in the water, it is comparatively easy to watch the act of fertilization and the subsequent development of the embryos. In the water a transparent substance envelops the egg, which holds the spermatozoa a short distance from the cell proper (Fig. 6). The only reason for believing that such a substance is present is the fact that preserved eggs still retain the circle of spermatozoa. The attraction of the male cell to the egg is believed by scientists to be of chemical origin. Although the egg is thickly surrounded with spermatozoa, only one is needed for fertilization, and after its entrance the rest are held outside by the formation of a membrane through which they cannot penetrate. Occasionally more than one spermatozoön enters the egg, but in this case the egg possibly fails to attain complete development.

(a) *Natural Fecundation.* — Judging from the enormous number of eggs and spermatozoa annually liberated by a single adult scallop, nature seems prodigal with her bounties; but on second thought it appears that an equilibrium has been established and that an abundance of spawn is needed to compensate for the destructive agencies which beset the scallop. It seems strange, perhaps, that the spermatozoa

should outnumber the eggs 1,600 to 1, as it only requires one spermatozoon to fertilize one egg. But as the small male cell has the active part of finding the egg, this again is a wise provision of nature, whereby this proportion vastly increases the chances of natural fecundation.

If only 1 scallop arrives at maturity from 3,000,000 eggs, it is sufficient, under normal conditions, to perpetuate the species. Naturally there is a vast destruction of eggs and young scallops, an important part of which is due to the loss of eggs through non-fecundation, *i.e.*, the eggs and spermatozoa not meeting in the water. There are a great many chances in nature against fertilization of the egg. Scallops may be some distance apart and the spermatozoa must travel far before they can meet the egg. Water currents, winds and other weather conditions may prevent this union. Fertilization is partly by chance, as the male cell can only be attracted to the egg from a short distance. Thus, if it were not for the abundant supply of sex products the race of scallops would soon be exterminated.

In artificial fertilization a large number of the eggs are not fertilized, and, failing to develop, soon decompose and pollute the water, thus causing the death of the more advanced larvæ. This shows that perhaps all the eggs given forth at one time from the scallop are not ready for fertilization and cannot develop, and it may be supposed that, under natural conditions, an indeterminate per cent. of the extruded eggs are incapable of development.

(b) *Self-fecundation.* — *Pecten irradians* is hermaphroditic, *i.e.*, both sex elements are found in the same individual. Pelseneer (9) asserts that: "In hermaphroditic mollusks the spermatozoa ripen before the ova; the hermaphroditism is therefore protandric. The hermaphroditism also is not self-sufficient, and the ova of one individual must normally be fertilized by the spermatozoa of another individual." *Pecten irradians* is an exception to this in that both the eggs and spermatozoa mature at the same time, and that self-fertilization frequently occurs although it is not the common method of reproduction.

In nature it is not usual for scallops to produce both male and female cells at the identical moment, and self-fertilization is therefore not as common an occurrence as when scallops are confined in aquaria. Scallops often shoot eggs and spermatozoa within as short an interval as 15 to 30 minutes apart. In numerous cases self-fertilization has been observed during the spawning experiments. The spermatozoa and eggs of the same scallop have been artificially mixed, and the early embryological stages followed. Whether these self-fertilized eggs would develop into mature scallops was not determined, as the development was only followed as far as the trochosphere larva, up to which period it was normal. Drew (1) and Risser (2) also have made observations on the self-fertilizing powers of the individual *Pecten irradians*.

Fertilization of the Eggs of Two-year-old Scallops. — In spite of

the fact that the second spawning of the scallop occurs during its old age, and that the majority of this species do not reach a second season, the eggs of two-year-old scallops may be fertilized and pass through the normal cleavage stages. Although there were some indications that the subsequent development under artificial conditions is not as satisfactory as that of the younger scallops, there is no proof that their development under natural conditions is anything but normal, or that they cannot produce hardy offspring. Naturally, as the two-year-old scallops are few in number their offspring are not numerous. Under artificial conditions as compared with the younger scallops they do not seem to produce spawn so readily and fewer larvæ in proportion are raised to the early swimming stage. These observations cannot be considered as conclusive, as the special Powder Hole set of 1907, already referred to, during 1909 furnished as healthy spawn as the 1908 set.

EMBRYONIC DEVELOPMENT.

The early life of *Pecten irradians* can be separated arbitrarily into two main divisions, (1) the embryonic or sub-veliger life, which comprises the development of the animal until it acquires a shell; and (2) the post-embryonic life of the young scallop before it attains adult characteristics.

The post-embryonic life is further subdivided into the (a) early veliger stage, when the animal is a free swimming larva with a straight hinge line (Fig. 17); (b) late veliger or prodissoconch stage, distinguished by the curved hinge and development of gills and foot (Fig. 18); (c) the dissoconch stage, where notable changes occur as a result of the "setting," that is, adjustment by spun byssus threads; (d) plicated stage, where the ridges and the furrows characteristic of the adult shell appear.

The embryonic development of *Pecten irradians* is in many respects so similar to that of its large relative, *Pecten tenuicostatus* Mighels, the giant scallop, so ably described by Dr. Gilman A. Drew (1) that it is difficult to present a complete account without a repetition of many interesting facts. For this reason special emphasis has been placed on the points of difference between the two species, and only general consideration given those of common interest. In reporting upon this phase of the life history of *Pecten irradians*, it is perhaps worthy of mention that the results here embodied, imperfect as they are, have been obtained from hundreds of scallops under different conditions and from four years of successive observations.

The Development of the Egg.

The development of the egg after fertilization is by the usual process of cell division, whereby the single ovum is transformed into a living mass of tiny cells. Like most lamellibranchs, in which fertilization

takes place externally to the parent, the scallop develops by the normal process of unequal cell division, and its subsequent growth as far as the prodissoconch stage is similar in nearly every respect to the development of the clam, oyster and quahaug.

The Polar Cells (Figs. 4, 5).—The first noticeable change in the external appearance of the egg occurs about thirty-three minutes after it is laid. At one part of the egg, which from this time forth becomes the so-called animal pole or region of the greatest activity, appears a small translucent globule, $\frac{1}{10}$ the diameter of the egg. This is known as the first polar cell, and is soon followed by a second body of similar nature, which pushes out behind the first in such a manner as to separate it from the egg. Both adhere to the egg by protoplasmic strands, such as described by Drew (1). With *Venus mercenaria* (the quahaug or hard-shell clam) the polar cells form beneath a thin membrane, and are held to the egg by strands from this source. Such a covering is not well marked in the scallop egg, which appears naked, and the protoplasmic strands may possibly have a different origin. The polar cells contain no yolk granules, as is shown by their transparent appearance. They remain with the egg through all the varied stages of cell division, and can be seen still adhering to the first ciliated larvæ, evidently disappearing during the early swimming stage.

The Yolk Lobe.—About ten minutes after the first polar cell is formed, the opposite side of the egg, now known as the vegetative pole, elongates, giving to the egg a pear-shaped appearance. The constriction at the small end is the so-called yolk lobe (Fig. 5) which forms a few minutes previous to cleavage. *Pecten irradians* differs somewhat from *Pecten tenuicostatus* in regard to the time of formation of the yolk lobe. In the case of the latter species, Drew (1) has shown that the yolk lobe appears previous to the polar bodies, and that it becomes prominent when the second polar body is formed, only to disappear and again to become prominent when the egg cleaves into two cells. The yolk lobe in the former was not seen until after the formation of the polar cells, and not until just before the first cleavage did it become markedly prominent. It forms in about three minutes, and is completed one minute before the first cleavage takes place.

The First Cleavage.—Soon after the formation of the yolk lobe and the differentiation of the egg into the animal and vegetative poles a constriction takes place parallel to the longitudinal axis of the egg, dividing the broad end into two unequal cells, the smaller one-half the size of the larger, with the polar bodies between them (Fig. 7). The actual time consumed from the beginning to the completion of the first cleavage varies from two to twelve minutes, but usually it takes about three minutes to effect the change. This first division occurs forty-six minutes after the egg is fertilized.

The action of the yolk lobe during this division is somewhat peculiar.

Previous to the first cleavage the egg has taken on a pear-shaped appearance, due to the formation of the yolk lobe. During cleavage this lobe in many of the eggs became so constricted that the dividing egg had a three-celled appearance. Then it gradually disappeared, in one case in the course of seven minutes, leaving only a large and small cell. The form of the different eggs during cleavage varies greatly, some dividing with scarcely the appearance of a yolk lobe, others with prominent constrictions.

The next cleavage (Fig. 8) divides the egg into four cells in a vertical direction, and passes through the animal pole nearly at right angles to the first cleavage plane, and a little to one side of the center. This division forms three small cells and one large, the latter holding the nutritive or yolk part of the egg, originally contained in the region of the yolk lobe. The second cleavage occurs from fifty-five to eighty-one minutes after fertilization, the average time being sixty-seven minutes.

The third division (Fig. 9) is in a horizontal plane, dividing the four cells into eight. The four upper cells, which lie next to the polar bodies, are much smaller than the lower ones, and from this time forth are designated as the micromeres, while the large lower cells are known as the macromeres. During the process of cleavage the upper layer of cells twists 45° , so that they alternate with the lower cells, furnishing an excellent illustration of the spiral cleavage so common in nature. The time of arrival at the eight-celled stage varies from fifty-eight to one hundred and ten minutes after fertilization, the average being about eighty-one.

From this time on the micromeres divide rapidly into smaller and smaller cells, during which the egg passes successively through sixteen, thirty-two, sixty-four, etc., celled stages, finally forming a layer around the macromeres. The average time of the sixteen-celled stage (Fig. 10) is about one hundred minutes after fertilization. Cell division continues until the single primitive ovum has become a compact mass of small cells surrounding four large cells, the macromeres, resulting in a type of the epibolic gastrula, which later becomes a true invagination by the further division of the macromeres. From a surface view the animal is merely a rounded mass of cells, still bearing the two small polar bodies (Fig. 11.) Soon the inner layer of cells forms an infolded cavity, the archenteron or primitive digestive tract, which opens to the exterior. The micromeres now make up the ectodermal, the macromeres the endodermal layer.

By this time the surface cells have developed cilia, and the animal acquires the power of locomotion (Figs. 12 and 13). It is important that the scallop become active at this period of its existence, as otherwise it would perish. In the laboratory the majority of the eggs settle to the bottom of the glass dishes until this stage is reached. Doubtless in nature the egg, unless held in floating masses or kept in suspension

by the currents, falls to the bottom, where it remains until it acquires cilia. The majority probably perish before they reach the swimming stage, either through not being fertilized or because of settling on unfavorable bottom.

The swimming period is reached from nine to twelve hours after fertilization, ten hours being the usual time. Little change has taken place in the size of the animal, and the entire scallop is hardly larger than the original egg. Development is rapid during the swimming period, not so much in size as in change of form from the early swimming gastrula to the trochosphere larva. There are three phases of development in changing from the early gastrula to the advanced trochosphere. (1) The animal is a mere rounded mass of cells covered with cilia. (2) The body has elongated, the blastopore or primitive mouth becomes more noticeable, and the cilia instead of being general are confined to a special portion of the body, which later proves to be anterior end (Fig. 14). In the course of two hours after phase 1, the cilia on the frontal cell at the anterior end of the body elongate until they attain seven-ninths the length of the body (ordinary cilia measure one-fifth the length of the body), and unite to form a bundle called the flagellum, which guides the swimming embryo. Ordinarily it has the appearance of a single last or whip, so closely are its parts united, but as many as six individual cilia have been counted in this bundle. The anterior end of the animal has in the mean time become larger and heavier, while the posterior half has elongated, giving the scallop a top-shaped appearance. (3) The third phase is marked by another invagination on the dorsal side of the animal, directly opposite the blastopore. This is the primitive shell gland which secretes the shell. Pelseneer (9) in considering lamellibranchiate mollusks as a class says of the shell gland: "During its extension it gives rise to a saddle-shaped cuticular pellicle, which becomes calcified at two symmetrical points, right and left of the middle line. These two centers of calcification eventually form the two valves of the shell. . ."

The transition from the early swimming gastrula to the advanced trochosphere is well illustrated by the development of the swimming powers of the young scallop. As soon as the embryo has acquired cilia it starts with a rolling motion, at first slowly, but later faster as it increases in strength, turning over and over on the bottom of the dish. This simple method of changing position is by a rotation on the longitudinal axis which might be compared to the movement of a top before it totters over. The embryo rotates in one place or hitches along in random directions. The rate of this action varies greatly, anywhere from five to twenty turns being counted in ten seconds. The cilia soon perform the functions of swimming organs, and the little animals rise through the water towards the surface, where they can get a better supply of oxygen. The first swimming movement is a compound motion

consisting of simple rotations plus revolutions. The prevailing revolution is clockwise, but the motion is intermittent and the direction can be changed at will. With the development of the flagellum, a definite direction of motion arises. The animal nearly always swims with the flagellum anterior, although one case has been observed where the animal swam in a reverse direction for a short distance. Possibly the flagellum serves to increase the speed, which becomes so rapid that it is difficult to follow the animal with a microscope of 41 magnification. The motion is now effected in a straight line by spiral revolutions along the longitudinal axis of the animal. This final motion is probably the culmination of the previous aimless rotations.

The Shell Gland.—The formation of the shell gland, which occurs twelve to fourteen hours after fertilization, marks a decided change in the character of the young scallop (Fig. 15). In the course of a few hours a thin transparent shell grows slowly over the animal, until it completely envelops the soft parts. At first the shell is so small that it scarcely covers the whole of the animal, which can be seen swimming through the water partly covered by the two thin valves. This shell is formed by the secretion from the shell gland, which becomes calcified at two points, forming the two valves. The hinge line at this early stage is flat and straight. At the same time, with the spreading of the shell, various changes of more or less importance, both in the anatomy and in the habits of the young scallop, have taken place, giving rise to a period in its development known as the veliger stage, perhaps the most critical and important period of its existence.

The Veliger Stage.

When reared in the laboratory the embryos reached the full veliger (shell) stage between seventeen and forty hours after fertilization, according to the temperature. Presumably the same time is true in nature, although the rapidity of development varies with the external conditions. The length of the veliger stage is likewise dependent on temperature and environment, the usual duration being about five to six days. During this period numerous changes of more or less importance take place, and the late veliger is an essentially different animal from the early form. It will be necessary, therefore, in describing the veliger stage, with all its involved changes, to arbitrarily divide it into two phases, the early (Figs. 16 and 17) and the late veliger (Fig. 18); and in describing the anatomical changes it will be more satisfactory, after a brief survey of the essential features of each phase, to trace the development of the individual organs separately.

The chief characteristics of the early veliger (Figs. 16 and 17) are: (1) an equivalvular shell slightly inequilateral, without definite structure, with a straight hinge line, no umbones being present; (2) a velum or ciliated swimming organ; (3) a primitive mouth lined with cilia,

leading into a cavity in the center of the body, the stomach, and an abbreviated intestine with a posterior anal opening; (4) an inconspicuous mantle; (5) anterior adductor muscle alone present; (6) size .093 millimeter. The increase in size from the trochosphere stage is due to the formation (Fig. 16) of a cavity between the body and the shell.

The late veliger is characterized by: (1) a shell of the same structure, marked by prominent umbones directed posteriorly; (2) a well-developed foot which has succeeded a degenerated velum as the swimming organ; (3) a more complex digestive tract, with palps, and a coiled intestine; (4) a conspicuous mantle; (5) a posterior adductor muscle, and the appearance of several gill bars; (6) size, .18 millimeter.

In studying the life history of nearly every large lamellibranch which begins its life external to the parent, there is a gap between the anatomical changes of the early and late veliger periods, as it is a difficult stage to procure specimens for study. It is only possible in this history of the scallop to give the changes in the different organs by comparing the early and late veligers, as we have not been able to identify with certainty the intermediate forms on account of the large number of species which so closely resemble each other, as they are collected in the plankton net at the surface.

The Shell. — The veliger shell of the Pelecypoda or lamellibranchiate mollusks has been aptly given the name prodissoconch by Jackson (4) to distinguish it from the succeeding shell, the dissoconch. With the scallop, I have taken the liberty to apply this term, which properly includes all of the veliger stage, to merely the late veliger, at which time it has acquired a form markedly characteristic of the scallop. Hereafter, when speaking of the prodissoconch shell, it refers only to the form of shell typical of the late veliger, as it remains differentiated from the succeeding dissoconch stage. In the early veliger, the shell consists of two valves of homogeneous structure joined dorsally by a ligament in a slightly concave hinge-line.

The change from the flat hinge veliger (Fig. 17) to the completed prodissoconch (Fig. 18), which marks the end of the veliger stage, is quite pronounced. The straight hinge line has given way to one of slight curvature, while the valves by their growth have formed prominent umbones, hiding the hinge line from lateral view. The umbones point posteriorly, but are less prominent than in the case of the oyster. The left valve is more convex than the right, and the right umbo is less prominent than the left (Fig. 19). In the completed prodissoconch and probably in the early veliger ten pairs of teeth can be seen along the hinge line, five on each side of a central slit (Fig. 22). The question of teeth has always been of interest in the classification of lamellibranchs. These are later either obscured or absorbed by the growth of the shell. The teeth of one valve fit into the depressions of the other, adding strength to the hinge. The shell remains homogeneous, except for fine lines of growth parallel to the free edge. Its calcareous composition is

shown by effervescence when tested with acid. The scallop differs from *Anomia glabra* at this stage by having no byssal notch in the shell.

The Velum. — The veliger derives its name from the larval swimming organ or velum peculiar to this period of its life. This organ, situated in the anterior part of the shell, consists of an elliptical pad, .046 millimeter in length, with a border of short vibrating cilia, and supporting in its center a long flagellum. It is capable of extension and contraction, whereby it can be thrust out of the shell or drawn in quickly by means of retractor fibers, which are fastened to the shell near the posterior part of the hinge, so as to give a direct backward pull. Two fibers go to the ends of the velum, the third to the center. When contracted, the velum folds in to the form of a bell, the round ciliated edges curving toward the central part, which bears the flagellum. When expanded, the velum opens like the unfolding of a flower, the ciliated edges curling outward. When the velum is extended outside the shell, as the animal swims, the whole mass shifts ventrally, leaving a clear space between the hinge and the body. The flagellum serves during this period as a sensory organ or feeler. The velum is of great use in swimming, and can rapidly propel the young scallop through the water by the lashing of its cilia in a manner similar to the action of oars in a boat.

The development of the velum can be traced from the ciliated region of the early gastrula, and the organ is a direct modification of the anterior ciliated area of the trochosphere larva. The frontal cilia, with the long central flagellum, have become more centralized and stronger, while the ciliated arc has formed a muscular pad capable of extension and contraction. The flagellum and cilia of the veliger stage are identical with those of the trochosphere, the only change being a modification of the supporting area.

While the transition from the veliger to the footed larva has never been completely observed in the scallop, it is doubtless identical with that of the clam, which is here described. This change takes place by the atrophy or degeneration of the velum and the simultaneous development of the foot. Several stages can be observed during this transition period: (1) the primitive veliger, with no foot or at best a rudimentary projection posterior to the mouth; (2) a reduced velum and a half-formed foot; (3) a small velum and a nearly complete foot; (4) no velum and a perfectly developed foot. During this period the mouth has advanced anteriorly and dorsally, following the disappearing velum, which vanishes in the region of the palps.

Habits. — Swimming in the earlier veliger stage is wholly by the velum, while later this organ is assisted by the foot. The very young veliger is less active than the older larva, and is usually found at the bottom of the dish with valves widely open and velum partly protruded. In this case, the movement merely consisted of turning in a circle, as the velum was not thrust out far enough to enable the animal

to swim rapidly in a straight course. Only when the velum can be completely extended does the larva attain full swimming powers.

When the velum is fully developed the animals become rapid swimmers, and can be found in great numbers through the water, more especially near the surface, where they can be taken in a net of silk bolting cloth. When placed in a glass aquarium, if left undisturbed, they can be seen by the naked eye as white specks as they swim through the water. If the dish is subject to any sudden jar, such as a sharp tap with a pencil, the young scallop quickly pulls in the velum and settles to the bottom with closed shell. After a brief interval the animal extends the velum with a hesitating jerky movement, until it is fully expanded, and then resumes swimming. The usual direction is with the velum ahead, the cilia on the edges lashing with a rowing motion which propels the animal in the same manner as a boat is propelled by a man seated in the bow. There is also a turning motion, which whirls the larva antero-posteriorly in either a clockwise or anti-clockwise direction.

The Foot.—As the animal passes into the late veliger stage the swimming powers of the velum degenerate, while the foot with its ciliated tip becomes the only organ of locomotion. The footed larvae swim by a kicking movement of the foot. It is natural to suppose that there is a transitory stage where both the velum and the foot are used. The foot, the most useful organ of the young scallop, makes its appearance in the prodissoconch stage, and for a long time serves as means of locomotion for the animal. It is a long, flexible organ, made up of both longitudinal and circular muscles, and entirely covered with fine cilia. On its tip or distal end are long cilia, comparable to the little tuft or cluster posterior to the mouth in the early veliger. The long cilia are at first useful in swimming, but as the animal becomes larger they become relatively less important. The tip of the foot is slightly cleft, as is shown for an older scallop (Fig. 27). On both sides of the foot in a median position are two vestibules, with several small granules rotating inside. These are the otocysts or organs of equilibrium. On the dorsal side of the foot, one-third the distance from the proximal end, is a prominence with a cleft opening, the byssal gland, the function of which has not culminated at this stage. The foot is capable of great extension by the contraction of the circular muscles, and is drawn in by the contraction of the longitudinal to lie in its normal curved position within the shell (Fig. 18).

The Adductor Muscles.—The primitive veliger has but a single adductor muscle, the anterior. In the dissoconch stage, the posterior adductor is the only one present, the anterior having disappeared. As is stated by both Jackson (4) and Drew (1), there must be an intermediate stage where both are present. I have obtained no actual proof of this, but in all probability a dimyarian stage, *i.e.*, having two muscles, must have been reached in the course of development.

The Gills.—The early veliger has no gills. They first begin to develop coincidentally with the formation of the foot as simple bars or ciliated filaments, capable of extension and contraction from the dorsal point of attachment. Starting from beneath the stomach they lie in folds along the upper part of the foot. When first seen, at the beginning of the degeneration of the velum, they scarcely consist of two folds, but before the velum has disappeared they number from four to five. The edges of the folds are lined with active cilia which keep up an incessant motion. These primitive bars, as seen in the prodissoconch (Fig. 18), are the paired beginnings of the inner gills. The outer gills develop at a later stage.

The Mantle.—At the time of the formation of the gills the mantle becomes noticeable as a thin, transparent covering just under the shell, although it has been functional before this period. By the time the dissoconch stage is reached, the free edge has thickened into fine folds and is lined with small cilia.

The Digestive Tract.—The digestive apparatus of the early veliger consists of a funnel-shaped mouth lined with active cilia, leading into a broad sac, the stomach, also lined with minute cilia, from which arises a two-lobed liver. The intestine is merely a straight tube opening posteriorly. With the prodissoconch veliger the digestive tract is obscured by the growth of the liver, which has assumed a greenish yellow color so that the coils of the intestine are difficult to distinguish. The mouth has travelled forward in a dorsal direction, the edges apparently having formed the palps, while the ciliated funnel has become the œsophagus. The intestine now has one or more coils, and, in order to carry on the more complicated process of digestion, opens dorsal to the adductor muscle.

Summary of Veliger Stage.

	Early Veliger.	Prodissoconch Veliger.
Shell,	Straight hinge, . . .	Prominent umbones.
Velum,	Present,	Degenerate.
Foot,	Absent,	Present.
Gill-bars,	Absent,	Present.
Mantle,	Invisible,	Visible.
Mouth,	Ventral position, . .	Anterior position.
Palps,	Absent,	Present.
Stomach,	Simple sac,	Simple sac.
Liver,	Small,	Large.
Intestine,	Straight,	Coiled.
Adductor muscle,	Anterior,	Posterior.
Size, . . . . .	.093 millimeter, . .	.18 millimeter.

The Dissoconch Stage.

The young scallop now enters upon the third stage of its development, the period of byssal attachment, which is comparable to *youth* in man. From structural differences of shell, which sharply distinguish it from the prodissoconch, it has been called by Professor Jackson (4) the dissoconch stage. The anatomical changes are so complicated that for the purpose of description several arbitrary subdivisions, illustrating successive periods of development, have been made. A table of these phases is appended in chapter VII. In the general description of the dissoconch period, especially in the section on anatomical development, reference is made to these subdivisions.

The chief characteristics of the dissoconch stage are the habits of byssal fixation and crawling. In a preliminary report the writer was led to include an intermediate stage between the free swimming veliger and the attached scallop, that of a free crawling existence. Later investigation has shown that the last two stages practically coincide, and that no line of distinction can be drawn. Evidently the power of crawling is supplementary to byssal fixation, and is of great service to the animal when it wishes to change its location or is torn away from its point of attachment. That young scallops have the power of byssal fixation immediately following the prodissoconch or at the very beginning of the dissoconch stage is shown by those attached to the raft spat boxes, described in chapter VII. In many of these scallops the dissoconch growth, scarcely one day old, had just started, yet they at once attached themselves, by a fine byssal thread, to the sides and bottom of glass dishes.

The subsequent changes in anatomy and shell formation can be more readily attributed to a complete change in habits, such as the assuming of a stationary life after a free-swimming existence, than the transition from swimming to the intermediate crawling stage, such as has been suggested by other investigators. Knowledge of the byssal attachment in the early part of the dissoconch stage shows that there is an abrupt change of life at this period, and gives a new interpretation to the structural differences.

The Set.—The oyster, according to Jackson (4), still possesses a velum when it "spats," or attaches itself at the end of the prodissoconch stage, and no foot has developed. "The preliminary fixation," he states, "is probably effected by means of the reflected mantle border, as described by Ryder, and is then immediately succeeded by a cementing conchyolin attachment at the extreme edge of the lower left prodissoconch valve." The scallop, on the other hand, before it sets has lost its velum and has developed a muscular foot, which acts as a swimming organ during the latter part of the prodissoconch stage. The set is made, not by any fixation of the shell, but by a fine thread, called the

byssus, formed by a gland in the foot (Fig. 30). It is interesting to note that in each case the attachment, though entirely different, comes at the end of the prodissoconch period, and that the organs of attachment and locomotion, owing to the absence of the foot in the oyster, are strikingly dissimilar.

The Shell. — The shell of the dissoconch stage (Fig. 19) is sharply separated from the prodissoconch by a well-defined growth line and by different shell formation. The prodissoconch has a smooth homogeneous structure lined with finely concentric lines of growth. The new growth is of an entirely different character, as the right or lower valve acquires a prismatic structure (Fig. 41), such as was described in *Ostrea* and *Pecten* by Jackson (4), in which each prism is separated by an intervening space. The structure on the left or upper valve, while not prismatic, is readily discernible in appearance from the prodissoconch. The first indications of coloring in the shell appear during the latter part of this period as little dashes of yellow or brown. The dissoconch shell has a smooth, even appearance, with no plications, and separated by regular concentric growth lines, which are used by the writer to mark off certain sub-stages. Probably these growth lines, as yet not eroded by action of water or subsequent growth, denote daily periods, tides or other intervals in shell formation.

With this stage the hinge becomes for the second time a straight line. During the first three sub-stages it is narrow, hardly four-sevenths the width of the animal, but later it increases relatively in width, until at the beginning of the plicated stage it is nearly the same length. In the early stages the hinge line is not absolutely straight, but inclines slightly upward at both ends. The inside of the hinge line is set with teeth, as described for the prodissoconch veliger (Fig. 22).

The form of the scallop gradually changes during the dissoconch period, as it grows from .18 to 1.20 millimeters. At first the shell rounds out anteriorly, while posteriorly it breaks directly down from the hinge line with a slight curve (Figs. 19, 20). The left or upper valve elongates anteriorly a slight distance beyond the right, covering in this region the byssal notch of the lower valve (Fig. 19). At a slightly later stage (Figs. 25, 26) the shell has formed in this region a "pseudo ear," which disappears as the animal grows larger, and again reappears at the size of 1.50 to 2 millimeters to form the true "ears" on both sides of the shell. Meanwhile, the posterior part of the shell has increased slightly faster than the anterior, causing the prodissoconch to assume a position anterior to the center (Fig. 28). Toward the close of the dissoconch stage the scallop loses its elongated form and takes on a semicircular appearance (Fig. 31). The various changes in form from the early veliger to the 2 millimeter scallop are shown in Fig. 77, which consists of eleven concentric camera outlines of different sized scallops.

The dissoconch scallop differs from the adult, in which the two valves are equal, by having the right or lower valve smaller than the left and less convex. This is undoubtedly a direct adaptation to its method of life during this period, the flat lower valve offering ease and assistance in crawling and attachment. *Anomia* offers an excellent example of the flattening of the lower valve in an attached animal, and the rounding out of the upper. The same is true of *Pecten irradians* to a slighter extent, as it is not attached so firmly nor for so long a period as *Anomia*.

The most interesting feature of the shell formation during this period is the development of the byssal notch and groove in the anterior part of the lower valve. The notch is the name applied to the indentation (Figs. 19-21), while "groove" refers to the hollow formed by the growth of the notch (Fig. 25). The notch first makes its appearance close to the prodissoconch, indicating that it starts at the time the animal "sets." By the time that phase 5 is reached a tooth-like process has formed on the notch (Fig. 29). These increase to three in number at the end of the dissoconch stage, and go as high as five or more in the plicated period. Similar teeth are found on the byssal notch of scallops less than one year old, as new ones are constantly forming, while the old are covered by the growth of the shell. Old scallops rarely have teeth on the byssal notch. If the shell is broken along the byssal groove in an adult scallop an entire ridge of these teeth can be seen where they have been covered by the growth of the shell. The use of these teeth is unknown, except that they are closely associated with the byssus, as is described in chapter IV. under the habit of byssal fixation.

The name byssal notch is probably derived from the fact that the byssus comes out of the same indentation in the adult. Perhaps at this stage a more appropriate name would be foot groove, as that organ, in crawling or in spinning the byssus, is thrust out of the opening. There is some difference of opinion as to whether the byssus or the foot is the cause of the formation of this notch. Jackson (4) says that it is formed by the folding back of the mantle, resulting in retarded growth in that locality (Fig. 21). Whether the foot or the byssus thread was the cause of this retardation cannot be stated definitely, although probably both are functional. Although the foot appears before the dissoconch stage it is used as a swimming organ. The byssal notch appears immediately after the prodissoconch stage, corresponding with both the byssal attachment and the use of the foot as a crawling organ. Therefore it can safely be concluded that the byssal notch is characteristic of this period, and is formed by the combined action of foot and byssus.

The Internal Anatomy.— With the development of the shell, corresponding changes have taken place in the internal anatomy, rendering the scallop better adapted to its new mode of life. Adult characteristics are now manifest, and the animal can be readily recognized as a scallop.

The specific development for each set of organs is given in detail under the section on "Anatomical Development," and it is only necessary to give here a brief résumé of the more important changes.

As the animal has entered upon an alternately stationary and crawling existence, the foot has become relatively the most important organ, and during the early part of the dissoconch stage reaches its maximum development in size. The ciliated tip and muscular body render it an active organ of locomotion, while the byssus gland provides the scallop with a means of attachment. The mantle, at first a simple, curtain-like fold with ciliated edges, becomes more specialized by the development on its outer edge of a few tentacles and eyes, which give it greater sensory functions. The four folds of the inner gills of the prodissoconch increase to twenty-two, and the outer gills make their appearance before the dissoconch stage is completed. The digestive organs increase in size, the liver becoming the most prominent, while the intestine elongates so that the anal opening is on the postero-ventral side of the adductor muscle. The posterior adductor muscle, which through this period has been capable of great expansion, as is shown in Fig. 23, so that the shell is often opened to an angle of 90° , has grown larger in circumference and has taken a more central position. The heart, consisting of a ventricle and two auricles, with its supplementary circulatory system, now first becomes conspicuous (Fig. 27). Altogether the internal anatomy of the young scallop has passed through the transition period from babyhood to the adult, and is now ready to take on the final characteristics of the mature scallop.

The Plicated Stage.

The plication stage, as the name suggests, marks the beginning of the radiating ridges or furrows which give to the scallop its beautiful fan-like appearance. These plications do not increase in number as the animal grows older. Figs. 33 and 34 show the beginnings of the plications in the shell, while Figs. 36 and 37 show a later stage. In the early plicated stage the form of the scallop is semi-circular, the height and width being approximately the same, while the hinge line is nearly equal to the width. The hinge line is now straight, but markings exist in the shell showing the former downward slant toward the prodissoconch, which in the early part of the plication period is asymmetrical, but later attains a median position, before it is covered by the rounding umbones of the shell. The true "ears" of the adult make their appearance as indentations on the lower sides of the hinge line, anteriorly and posteriorly, when the scallop has attained about 2 millimeters in size. During this stage they are much less pronounced than in the adult, while the hinge line itself is relatively longer, nearly equaling the width of the shell.

The byssal notch, which inclines slightly upward toward the prodisso-

conch, has now become deeper and is lined with several teeth along its inner border. The number varies from one to six or more, the older teeth being less pointed than the last formed. In Fig. 39 there is a secondary furrow dorsal to the main groove, and a serrated structure near the hinge line, consisting of seven sharply pointed teeth, the origin and use of which are unknown.

The dorsal view of the shell of *Pecten* at this stage (Fig. 38) shows the relative size of the umbones and the hinge line. The left valve is deeper than the right and the umbones point slightly posteriorly. The line of separation of the prodissoconch and dissoconch growth is sharply marked, showing how the two valves, which were close together during the prodissoconch stage, have been spread apart by the new growth of the valves. This period is just previous to the disappearance of the prodissoconch, either by the wearing away of the shell or by the growth of the shell.

The exact duration of the plication stage cannot be given, as the transition to the adult is gradual. Perhaps the end of this period should come when the animal has attained general adult characteristics. If such a definition be taken, the arbitrary size may be assigned as 4 millimeters, for by that time the visceral mass is well defined, completing the adult anatomy of the scallop. Unless some standard were taken, it would be impossible to tell just when the plication stage ceased and adult life began. Another view would have the plication stage followed by a period of youth, and consider that the adult life was not reached until the animal was a year old. This, perhaps, is a better division, although the characteristics of the youth and the adult are practically the same.

The Internal Anatomy.— Few new organs arise during this stage, which is mostly concerned in the development of those already formed. The most prominent feature is the appearance of the visceral mass with the reproductive organs, which are first noticeable at the size of 3 millimeters. The visceral mass grows down from the ventral surface of the foot, which becomes relatively smaller with the growth of the animal.

At the size of 3 millimeters, the mantle has increased by the formation of a set of guard tentacles, which are situated on the perpendicular flap. The eyes have increased until they number sixteen or more on each lobe of the mantle, while the tentacles have correspondingly increased in size and number. The circulatory and the nervous systems have become more complicated, to meet the requirements of the growing animal, which now has acquired the power of swimming by valvular contraction. The digestive system has expanded, the palps becoming ruffled around the mouth, and the intestine elongated in the region of the visceral mass. The adductor muscle has increased greatly in size and can be seen to consist of two distinct portions. By the completion of the stage, the animal has attained all the organs and characteristics of the adult scallop.

Anatomical Development.

In order to insure a unified and connected narrative, it was thought best, even at the risk of repetition, to trace the development of each organ or set of organs separately. Wherever opportunity is given the reader is referred to other portions of the report for supplementary reading. In tracing the outline of the early life history of the scallop the shell has been taken as the unit of description, and therefore its development need not be treated separately, and only the soft or internal parts of the animal need exemplification. Constant reference is made to the various stages outlined in the table in chapter VII., and to the illustrations, so as to present a connected account without unnecessary description.

The Mantle. — A description of the structure and functions of the mantle of the adult scallop is given in chapter II., and it is only necessary to recapitulate certain points which bear directly upon its development. The mantle is a thin bilobed membrane closely lining the interior of the shell and enfolding the body of the animal. The free edges form thickened flaps, which are brilliantly colored and lined with rows of sense organs, eyes and tentacles. The functions of the mantle are: (1) shell secreting, as the growth of the shell is due to the secretions from the mantle; (2) protective, as it enfolds and guards the body, and is largely instrumental in swimming and feeding; (3) sensory, as the numerous tactile appendages and the circumpallial nerve render it sensitive to the slightest stimulus.

There is a steady development from the primitive mantle in the young scallop to the highly specialized organ in the adult. It can be deduced, from the changes which take place during the embryological and post-embryological development, that the early ancestor of the scallop did not have such highly specialized functions, which only developed when the animal assumed its present dangerous mode of life, where it depends upon its nervous mechanism to warn it of impending danger.

The primitive mantle of the young scallop is a simple bilobed fold joined along the hinge line, and is first visible in the prodissoconch or late veliger stage. In the early veliger, although probably present to enable the formation of the embryonic shell, it was not noticed. It evidently attains prominence during the prodissoconch stage as a definite mantle, common to all lamellibranchs, similar, except for the crenulated edges, to that of the adult quahaug. At this time it appears entirely separate from the degenerate velum, whereas in the early veliger it was indistinguishable. The animal can extend the mantle slightly beyond the shell, and by means of retractor muscles withdraw it to about two-thirds its natural size. Even at this early period the mantle serves as a sensory organ, as the edges are lined with minute cilia and simple folds are already noticeable on the borders.

During the dissoconch or attachment stage, the mantle first takes on characteristics which differentiate it from the early stages of other forms. The edges become more folded and knob-like projections gradually form at definite places on the border, some to form tentacles, others the eyes of the scallop. (The development of the eyes and tentacles will be considered separately under "Sensory Organs.") The retractor muscles become stronger, and the mantle is now capable of greater extension and contraction, withdrawing at points where irritated. As the animal grows larger the number of retractor muscles of the mantle increase and are attached in a widening semi-circle far down the interior of the shell, so that only the outer portion of the mantle hangs free.

Another important functional change takes place when the so-called flap of the mantle is formed. This is a thin outgrowth in a perpendicular direction along the entire edge of the mantle, except just beneath the "ears" near the siphonal openings. The flap, when first formed during phase 6, is entirely plain, but soon is ornamented with a row of small tentacles called by Jackson (4) "guard tentacles." With the formation of the guard flap the animal has become a specialized scallop, differing from other lamellibranchs. The valves are now held apart, when resting, in such a way that the opposite flaps almost close the intervening space. Water can be taken in and shot out of the shell, giving the scallop the power of swimming.

Closely allied in function with the guard flap is the formation, during phase 5, of what is known as the pseudo-siphon, which arises as a transparent conical projection from the median posterior border of the mantle. This organ is formed by the conerescence of the mantle edges, and is not a true siphon, as is found in the clam and quahaug. Functionally this pseudo-siphon acts as an excurrent canal to eject water from the shell. Although it is not used for the purpose of swimming, as is the case with the same region in the adult scallop, it assists the animal at this period of life in crawling, as simultaneously with the contraction of the foot a stream of water is ejected from the pseudo-siphon. After each flow of water the siphon is retracted again, to be extended when the next stream is forthcoming. The pseudo-siphon disappears before the scallop reaches adult size, and is evidently only functional during the crawling period.

The mantle, particularly the edge, is beautifully hued with many colors. The mantle of the scallop at first is a transparent white, which gradually takes on the colors of the adult mantle. The intensity of the color varies greatly in the different scallops and is as unexplainable as the variety of colors in the shell.

The Sense Organs. — The scallop has a well-developed sensory system of specialized parts, each of which contributes to the maintenance of life and to the protection to the animal.

(a) *Tentacles.* — The tentacles in the adult scallop line the border of

the mantle. There are two kinds: (1) the large, highly extensible tentacles, lining the outer edge of the mantle, called by the writer "mantle tentacles" to distinguish them from (2) the inner or "guard tentacles," which lie on the edge of the perpendicular mantle flap. The "mantle tentacles" comprise several rows, apparently without any definite arrangement in the adult. When extended they have the appearance of long, slender white bars covered with minute conical projections, each tipped with a hair. The "guard tentacles" differ from the former in extensibility and function. They extend nearly the entire edge of the mantle flap, except in the region of the two siphonal openings below the "ears," and evidently act as strainers to keep out foreign substances from the mantle chamber.

The first specialization of the mantle border, the tentacles, appear when the growing condition of the animal demands sensory functions. They appear soon after the scallop passes the size of .5 of a millimeter, just previous to phase 5, when they can be seen fairly well developed. The first tentacles were noted as conical papillary projections .04 of a millimeter in height, tipped with single cilia (Fig. 44a) on the border of the ciliated mantle. Soon another rises close to the first, or more likely there is a division into two with a granular core between (Fig. 44b). The growth continues by repeated subdivisions and the extension of the core part of the mantle until a colony of these projections is formed (Fig. 45), covering a single tube of blood spaces, nerves and tissue, the tentacle proper. The papillary projections radiate from the stalk in such a manner as to give it the appearance of a pineapple (Fig. 46). Such projections are noticeable on the tips of the tentacles during stage 5 (Fig. 29).

The first tentacles to form are in the ventral region of the mantle (Fig. 27). When the young scallop has nine large tentacles on each mantle lobe, it has seven eyes, which alternate with tentacles. At this stage there are nine slight secondary tentacles which arise between the large ones and in definite relation to the eyes (Fig. 29). As the scallop grows the tentacles increase rapidly by this method of interpolation, with the result that there finally is apparently no definite arrangement of tentacles and eyes. The first nine tentacles may be styled primary, as they are much larger than the others, which, taken in the order of their occurrence, are called secondary, tertiary, etc. It is interesting to note (Fig. 29) that no primary tentacle is near the central region of the pseudo-siphon, but that there is one on each side. In scallops of 1½ millimeters these tentacles when extended measure two-thirds the height of the animal. The "guard tentacles," on account of their function, are quite different in appearance from the "mantle tentacles," being less extensible and heavier.

There are several uses for the tentacles of the young scallop, especially the primary, which are not functional in the adult. In *floating*, the small animal opens the shell, extends the tentacles to full length, and,

turning the body with right valve uppermost (the reverse of the natural position), maintains itself on the surface of the water. This habit has been observed in numerous cases in the aquarium in which scallops were confined. In scallops over 1 millimeter it appears to be accomplished by the spreading of the tentacles.

Observers, as Jackson (4), have stated that the animal is assisted by the tips of the tentacles in crawling, more particularly in climbing, during which the tentacles cling to the sides of the glass. Whether the extension and clinging of the tentacles is any great help to the foot in climbing is a matter of doubt, but they undoubtedly rest on the glass and are extended during both swimming and crawling.

The chief function of the tentacles is sensory. Often the tentacles of the adult do not respond to external stimuli, as would naturally be supposed, and in the case of repeated stimulation often fail to react at all. In scallops of 2 millimeters the tentacles may be made to contract separately by mechanically stimulating one at a time. This nervous reaction is not general, but if the whole animal is suddenly jarred all the tentacles are withdrawn with surprising swiftness. The tentacles of scallops of this size render the animal more sensitive than the smaller scallops, which do not have the full development of the tentacles. Thus the sensory nature of the tentacles is proven, and the subsequent inactivity of the large adults must be accounted for in other ways.

(b) *The Eyes.*—The most prominent feature of the mantle border is the fringe of brightly pigmented eyes, which are thickly scattered along the edge. In the adult there is great variation in the number, size and order of arrangement. These eyes are comparable with those of higher animals, and evidently have a sensory function.

As stated by Drew (1) the eyes are closely allied to the tentacles, and are in fact derived from the same source, being nothing more than modified tentacles. Their situation, origin, time of appearance, arrangement, all indicate that the eyes and tentacles are fundamentally the same.

The eyes make their appearance during phase 5, when the first or primary set is developed just after the primary tentacles are formed. The two lower or ventral eyes are formed first, then the eyes near the hinge line, and the intermediate ones soon after, numbering seven on each lobe of the mantle. The color of the eyes varies at this age from a brown to a blue. As can be seen in Fig. 29, the primary eyes and tentacles are arranged definitely, the eyes being situated on slight projections on the outer fold of the mantle between the tentacles. The successive development of the eyes is like the tentacles by the formation of secondary, tertiary, etc., sets between the primary eyes, at first alternating with the tentacles, but later apparently without definite arrangement. Although the visual function of the scallop's eye has been a matter of much dispute, there is but slight question that the eye has its use as a sensory organ.

(c) *The Otocyst*.—The otocyst, or organ of equilibrium, is situated in the foot in the young animal. It is first seen in the scallop of the prodissoconch stage as two vestibules of small size, one on each side of the foot. Inside the circumference is a clear fluid in which several small granules are constantly revolving (Fig. 20), evidently due to ciliary action. These remain prominent in the foot as long as that organ is relatively the largest part of the body, but are gradually lost sight of in the visceral mass of the adult scallop.

The Gills.—The gills form during the transition period from the early veliger to the prodissoconch stage, when they are observed as simple primitive folds lined with vibrating cilia. At the beginning of the dissoconch stage the gill is a bar folded into four simple filamentous processes, covered on the outer edge of the folds by rapidly stroking cilia (Figs. 18 and 20). Later stages show that the bar filaments are added ventro-posteriorly, first appearing as bud-like processes. The gills then consist of simple bar filaments so arranged with the longer ones dorsal that the whole gill has a semi leaf-like appearance. At the end of the dissoconch period these filaments number between 20 and 25, while the more mature dorsal bars became enlarged at the free end, due to their turning back upon themselves. At this time there are two gills, one on each side of the body, which are the inner gills of the adult. This later growth marks the beginning of the inner lamella although the filaments are still separate. The scallop is about 1 millimeter (about $\frac{1}{25}$ of an inch) in size at this time.

The next change is the formation of two outer gills, which mark the characteristic structure of the adult. Just previous to the appearance of the outer gills the animal has two inner gills of about seventeen filaments. Small "buds" arise on the upper edge at the posterior end of the gill, and increase rapidly in size and number. It is curious that the development of the outer gills starts at the posterior instead of the anterior end, exactly reverse to the formation of the inner gill. In a $1\frac{1}{4}$ -millimeter scallop sixteen filaments were counted on the outer gill, in a 1.8-millimeter scallop twenty-eight, and by the time the animal had reached the size of 3 millimeters the gills had the same appearance as in the adult. The inner gills are reflected inward, the outer gills fold outward to form the second lamella.

The later changes are more complicated and not so conspicuous. The filaments appear to become united, but on close examination this union is found to be due to the interlocking of ciliated discs on the posterior and anterior sides of each filament, giving the appearance of interfilamental cross bars. The filaments are joined in groups or bands of seven or eight. A 4-millimeter scallop has about ten bands, a 5-millimeter specimen twenty-five. The lamellæ are also attached at intervals by a fine septum.

The gills are at all times very sensitive. When touched with a pencil

they immediately contract. If a few drops of formalin are placed in the water near a small scallop a sudden clapping of the valves frequently shoots out a detached portion of the gills.

The Adductor Muscle. — According to Jackson (4) the revolution of the axis has brought about the loss of the anterior and retention of the posterior adductor muscle in the adult Pecten. Naturally, as with the oyster, there is one period of life, the early veliger stage, when the anterior adductor is present. Then follows an intervening stage where both are presumably present, and finally, by the time of the dissoconch stage, the anterior adductor has disappeared. Sharp (15), like Jackson, favors the view that the mechanical shifting of the axis of the shell has caused the atrophy of the anterior and the subsequent enlargement of the posterior adductor. In the adult the muscle is formed of two parts, a large anterior and a small posterior division. The relative increase in size of the muscle between 3 and 10 millimeter scallops is more rapid than the formation of the shell, the muscle increasing sixteen times, the shell only eleven times, in volume, and is possibly due to the need at this period of a larger muscle.

The Foot. — As the functions of the foot are given in chapter IV., under "Locomotion" and "Attachment," little needs to be said here. From the relatively largest organ in the scallop during its dissoconch stage, the foot rapidly becomes smaller, owing to degeneration and lack of use, until in the adult it is but a small projection on the antero-dorsal surface of the visceral mass.

The Visceral Mass. — The degeneration of the foot marks the growth of the visceral mass, which contains the reproductive organs and the coils of the digestive tract. It is first noticeable to the naked eye in the 3-millimeter scallop as a mere speck on the ventral surface of the foot. The reproductive organs are the last to mature and the last to be of use to the animal before its decline, which theoretically starts at the completion of spawning. Even at this early stage it is covered with the black pigment so prominent in the adult. A white streak running along the anterior edge marks the situation of the testes. The rest of the mass is covered with the pigment. The surface area of this mass for a 13-millimeter scallop is ten times greater than for a 3-millimeter animal. The intestine does not form a part of the mass until the scallop has attained a size of 8 millimeters, when the coils are enveloped. The visceral mass continues to increase in size until in the adult it is the largest part of the body.

The Digestive System.

(a) *The Palps.* — The palps are formed soon after the disappearance of the velum, and there possibly may be some connection between the two as the velum disappears in the vicinity of the palps. At first they are simple folds, as in the average lamellibranch, and not until later do they assume the ruffled form which is characteristic of the adult.

(b) *The Mouth and Œsophagus.*—The primitive mouth and œsophagus in the veliger consisted of a simple ciliated funnel leading into the stomach. At this period the edges of the mouth were covered with cilia, and the palps had not made their appearance, the only fundamental difference between the mouth of the veliger and of the adult.

(c) *The Stomach.*—The stomach of the veliger can be discerned beneath the liver through the transparent shell. The walls are lined with cilia. The adult stomach is more specialized by the formation at the posterior end of the articulating receptacle for the head of the crystalline style, by its larger size, and the ridges and folds which line its inner surface. Its development is gradual with the rest of the soft parts of the scallop, but cannot be traced in the young scallop after the veliger stage, owing to the dark covering of the liver.

(d) *The Liver.*—The liver appears in the veliger stage as two glands on each side of the stomach, and rapidly spreads out to cover that organ, so that in the developed veliger the most conspicuous object is the large liver mass in the center of the animal, with its granular colored appearance. As the scallop grows older, the liver takes on a darker color, which in the adult is an extremely dark brown, whereas in the young scallop, even up to 15 millimeters, it is a light brown or occasionally a yellow brown.

(e) *The Intestine.*—The intestine of the veliger when first formed is a simple tube curving downward and backward from the stomach. In a few hours the digestive processes have necessitated greater use of this organ and it has accordingly elongated by forming a coil in the upper part of the mantle chamber above the stomach and liver. The entire length of the tube is lined with cilia, and the food particles can be seen rotating within. The successive development of the intestine, exclusive of the formation of the crystalline style, which lies in a folded groove in the portion near the stomach, is chiefly that of elongation by means of coiling. When the scallop attains the size of 8 millimeters the coils of the intestine are inclosed by the visceral mass, or rather are seen to be enfolded in that substance, and are carried ventral as the mass increases in size. The anal opening passes during this development from a position dorsal to the adductor muscle to a more ventral situation in the adult, thus further increasing the length of the digestive tract, which passes through the central chamber of the heart.

Coloring of the Shell.

The numerous color variations in the shells of young scallops render them conspicuous among other objects on the tidal beaches. Scallops are found of all shades, ranging from the plain color to the striped varieties, with hardly two alike, and are on this account often gathered for ornamental or decorative purposes. The popularity of the scallop shell is ancient, as history tells us that this shell was the device on the

shield of many a crusader, and that through all ages it has been regarded as an object of beauty.

Naturally, various questions on the subject of shell coloration arise, such as (1) the nature of the coloring matter; (2) where and how it appears; (3) the variations; (4) do scallops change color? (5) is color due to inheritance or environment? In connection with the growth experiments on young scallops the following notes were made.

Coloring Matter in the Shell. — In scallops from 3 to 10 millimeters the brown coloring matter is the predominating shade. When mounted on a slide after having been treated with acid the colored shells leave a brown outline of various intensities on the glass, according to the depth of the color, while the pure white are barely discernible in outline, showing that the brown coloring matter resists the action of the acid. Other colors, as black and red, are of different origin and disappear under the action of acids.

The Appearance of the Color. — The lower or right valve of the scallop shows the color best. The upper valve is usually darker, of plainer hue, and covered with growths such as eel grass, sea lettuce, *Enteromorpha* and numerous smaller plant forms. In the young scallops the color of the two valves is the same, and only when the upper becomes coated over is any difference apparent. In the adult the lower valve is much lighter in color than the upper.

The time of appearance varies greatly. Albino scallops, which do not seem to have any coloring matter in the shell, are found in all sizes up to $1\frac{1}{2}$ inches. As they grow older the pure white color takes on a yellowing or grayish hue. Scallops the size of the head of a pin may have more color than scallops the diameter of a lead pencil. The prodissoconch is unpigmented; occasionally in the dissoconch stage little spots of color make their appearance, but no decided coloration takes place before the plications begin to form, when the scallop assumes in a minor degree the color patterns of the adult.

Color Variation. — The color of the shell varies greatly, especially with the young. All varieties from a pure white to a grayish-black, as well as a red variety, can be distinguished. The common marking is a mottled or striped appearance, undoubtedly the intermediate forms between the pure color types, as it is possible to arrange a series of shells showing these gradations. The color marking of the young scallops offers an excellent field for the student of variation.

Young scallops from $\frac{1}{4}$ to 10 millimeters can be readily divided into two main classes, using color as a basis of separation. Some are dark brown with a white fringe, while others range from a light yellow to a transparent white. It seems strange that scallops of the same set and size should present so much difference in color, and that different colors are often found on the same place of attachment.

In white scallops 2 to 3 millimeters a yellow pigment is frequently found in the grooves between the ridges, whereas in the adults these

furrows are colorless. Yellow markings are found on these small scallops below the hinge line in scattered patches about the umbo.

Do Scallops change Color as they grow older? — In 1906 the following experiments were made: Scallops of the 1906 set, ranging from 10 to 20 millimeters, were obtained from Stage Harbor, Chatham. These were sorted according to color and placed in wire baskets and suspended from the raft at Monomoy Point. On Sept. 7, 1906, they were put on the raft, and on Oct. 23, 1906, the color changes noted. A similar experiment was made with smaller scallops, about 3 millimeters in size, from August 15 to September 15.

These two observations indicate that there is a slight change in color from white to medium and from medium to dark, or that the scallop shell acquires as it grows older a darker shade. The dark scallops always remain the same, while the light-colored ones gradually take on a darker hue which never becomes very intense. Scallops between 3 and 12 millimeters vary in deepening their color, some requiring one week, others three, before any appreciable change is noticeable.

Is Color hereditary or due to the Environment? — The color of the shell seems to be an inherent quality and not influenced radically by the environment. An orange-colored scallop is always orange color, as has been shown by keeping record of the same colored scallops in wire baskets, and a small orange-colored scallop will always remain the same color, no matter how large it becomes. Color is not wholly unaffected by environment, as modifying changes occur; but in the main it is a constant quantity. The nature of the surface to which the scallops are attached does not seem to determine the color of the shell, as on light-colored wooden boxes 150 out of 1,100 scallops were dark colored, while the remainder of the scallops, which measured from 2 to 3 millimeters, were of a lighter hue. This shows that environment does not regulate the color formation of the shell, as both dark and light colored scallops are found on the same surface. It is perhaps worthy of notice that the majority, 86½ per cent., were light colored, while the rest, only 13½ per cent., were dark. The conclusion is that environment, while perhaps tending to modify the coloration, does not determine the true color of the scallop, which is an inherent quality in the animal.

An interesting experiment could possibly be made in regard to color inheritance if certain mechanical difficulties in the line of artificial propagation could be overcome. It would be of scientific interest to know whether scallops of a certain color would transmit this color to their offspring, and if so in what proportions. To accomplish this it would be necessary to have inclosed spawning ponds in which the scallops of the required color could be separated from the rest. At present, owing to the difficulties in the breeding of scallops, this is not possible, and an experiment of this nature will have to be postponed until artificial breeding is more fully perfected.

CHAPTER IV.—HABITS.

The story of the scallop would hardly be complete without some mention of its interesting and curious habits, which not only explain the anatomical structure, but also throw further light upon the life history. The methods of life of the young scallop are for the most part different from those of the adult, and are typical of stages in the development of the animal. A change in the function of an organ causes a corresponding change in its form, and practices once useful are discarded for others better adapted to the needs of the growing animal. Throughout early life can be traced a steady development, culminating in the adult method of life. For this reason the habits of the young, with the exception of swimming and resting, have been considered separately in the following chapter, and as far as possible arranged in logical sequence.

ATTACHMENT.

After the free swimming period of its early existence, one of the most prominent habits of the young scallop is the power of *attachment*, which occurs at the completion of its embryonic existence. This function not only proves a great help in growth, marking a new era in shell formation, but renders the immature animal less liable to attack from its numerous enemies.

The Set.—The “set” takes place when the young scallop attaches itself to any foreign object by means of threads secreted from a gland in the foot. The animal, at the proper time, settles or strikes against some object in the water, and clings to the point of attachment with its foot until the thread or byssus is spun. The frequency of “set” on eel grass is best explained by the hypothesis that the swimming scallop at this critical period of its life is carried by the current against the upright blades, where it clings with the foot until the byssus thread is formed. Larger scallops have been observed to swim to the sides of the aquaria and support themselves on the slippery glass by the foot alone until the attachment by the byssus was accomplished. The great numbers of young scallops found on the sides of spat boxes lowered from a raft moored in 20 feet of water show that the means of first attaining this attachment was by clinging with the foot when the animal came in contact with the box.

Young scallops attach themselves to eel grass, shells, stones, etc., but are generally first noticed by the fisherman on eel grass or sea lettuce, where they remain until they reach adult age. Scallops are found on both the upper and the under side of eel grass, usually 3 to 6 inches from the bottom being the locality of the heaviest set. *Ulva* (sea lettuce) seems to offer a better place of attachment than eel grass, as it may be carried for miles by the currents and “seed” scallops may

be transferred in this way from one locality to another. Shallow flats covered with thick eel grass are usually the most productive of heavy "sets," although the exposed nature of these flats during the winter often causes a severe mortality among the young scallops.

The exact conditions governing the set in any one locality are difficult to observe. The primary requisite is something to which the attachment can be made. This is usually eel grass. In a number of cases heavy "sets" are found in the still water on the sides of a swift current. This is often the case at the entrance to harbors where eel-grass flats line the channel. The spread of the incoming or outgoing waters carries with it the young larvæ, which, striking the eel grass in the still water, settle upon the waving blades.

The Byssus (Fig. 43).—The young scallop after its free swimming existence attaches itself by slender strands of hard, gelatinous material to the first suitable object with which it comes in contact. This bundle of threads is called the byssus, and is similar in function to the anchoring strands, the "beard" or "weed," of the common black mussel. The number of fibers composing the byssus depends upon the size of the scallop and the length of time attached, as but one thread is formed at a time, and the total number is not at once completed. As the scallop increases in size, the number of strands increase in proportion to the added weight. The environment may also determine the strength of the byssus, as scallops exposed to the strong winds and wave action necessarily need more anchoring strands.

The byssal threads pass from a gland in the foot out through an indentation in the lower or right valve of the scallop to the surface of the foreign object to which they are attached by minute discs. This indentation, directly under the anterior "ear," is the so-called byssal notch, which has already been described in chapter III. Along this groove are little projecting teeth or knobs, which develop in the later part of the dissoconch stage soon after the attainment of the byssal attachment. The use of these teeth is not known, but appears to be related to the byssal habit. Possibly they are of use in separating the strands. In scallops under one year of age these teeth number four to five, but in the majority of old specimens they are entirely absent, evidently disappearing when the byssus becomes practically useless, as the last formed teeth are rounded instead of sharply pointed. The manner of disappearance is readily shown by breaking the valve along the byssal groove and observing the line of teeth which have been enveloped in the adult shell. As they are formed at the same time that the byssus becomes functional, and disappear when that organ is no longer of use, there seems little doubt that their use is closely correlated with that of the byssus.

The following excellent description of the process of byssal fixation is given by Jackson (4):—

Lying on the right valve, the foot is extended on the surface of the dish, the flattened distal portion taking a firm hold as if about to crawl. This position is maintained for a moment or two and then the foot is withdrawn within the body; by the motion of retraction it draws out, or spins, the byssal thread, which the creature had fixed to the surface of the dish while the foot was laid closely against it. Soon the foot is again extended, pressed flatly against the dish, and another byssal thread is spun. The second byssal thread is always attached at a point a little removed from the point of fixation of the first thread; sometimes the two are separated by a distance of two or more millimeters. Additional threads may be spun; but three was a common number with specimens in confinement. Those on the bar, especially the larger individuals, frequently spun a large number of threads in the byssus. The byssal gland is situated in a proximal cleft-like depression in the foot separate from the more distal cleft-like depression which serves the animal in crawling, so that between the two there is a slight interspace without a cleft. Frequently when forming the byssus the foot may be arched up in this interspace, the hold being maintained by the tip of the foot and at the same time the byssal cleft being pressed closely against the glass, so as to make the fixation of the byssal thread. While spinning the byssus the scallop is preoccupied, and pays little attention to pricks or stimuli which at other times would meet with immediate response.

The following notes, which give additional information as to the length of time, were made on a 6-millimeter scallop confined in a small aquarium (Figs. 58-60).

The scallop lay in an unnatural position on its left or upper valve on the bottom of the glass dish. At 10.15 it extended its foot perpendicular to its body, lashing it to and fro with a wavy motion, until it was extended to its full length. Then, at 10.15½, it placed the tip on the bottom in a cautious manner. Soon after attaching the tip the scallop contracted the foot, snapping its valves in such a way as to force a jet of water from the posterior edge of the shell. This movement forced the body ahead with a partial turn. The scallop thereupon withdrew the foot, shooting two additional jets of water from the posterior pseudo-siphon. During these maneuvers a one-stranded byssus had been formed and was completed by 10.17. The byssus gland, meanwhile, had been in contact with the bottom of the dish, and the thread was formed by the opening of the groove and the hardening of the horny material by contact with water. Another scallop of the same size was twice observed to spin a byssal thread in four minutes, each time swimming through the water with foot extended in the interval between the attachments.

Period of Attachment.—The scallop can cast off the byssus at will, and soon spin another. The threads are broken off at the byssal gland, where they are closely united, and left adhering to the object of attachment (Fig. 43). This habit is altogether voluntary or under the effects of external stimuli. The early life of the scallop thus consists of a

series of attachments and dislodgments, with intervening periods of crawling or swimming.

The power of byssal fixation is first noticeable at the beginning of the dissoconch stage, when the young animal is found on eel grass and other objects. The free swimming period of the veliger has just passed and the scallop has entered upon a new existence, that of crawling and attachment. The scallop retains the power of byssal fixation throughout life, but seldom makes use of it after the first year. Scallops fifteen to sixteen months old have been frequently observed fastened to eel grass and to each other, showing that byssal attachment even at this late period in life is by no means uncommon. Perhaps scallops over one year old find little use for the byssus, as, owing to their size, there is less danger of their washing ashore in heavy winds. A twelve-month scallop has been seen to attach itself to the bottom of the aquarium twice within forty-eight hours.

Observations on the Attachment. — The byssal thread is strong and flexible, as the 6-millimeter scallop when firmly attached can be revolved at least 360° without breaking the strands (Figs. 52-54).

A curious attachment was noticed in a 2½-millimeter scallop on Aug. 3, 1908. The scallop was hanging by a byssal thread apparently from the surface of the water. The distal end of the byssus seemed attached to a small bit of mucus on the surface of the water, which was bowed down by the weight of the scallop. The valves of the little animal were apart, the tentacles extended, and the foot was lashing around with a wavy motion. The point of attachment was touched with the tip of a pencil, whereupon the byssus stuck to it so that the scallop could be raised to the surface and towed around the dish. The pencil point was then lowered gently in the water and the scallop remained suspended from the surface as before. This was repeated with the same result. The pencil was thrust through the water until it touched the scallop, which cast off its byssus at once.

Young scallops swim with the foot extended, and if the foot comes in contact with an object, such as the side of the aquarium, the animal claps the valves rapidly, as if to keep its balance until the foot becomes firmly attached. The movement might be likened to the fluttering of a hen when flying on to a roost. The foot is then drawn in, and the animal remains hanging to that corner of the shell by means of a quickly spun byssus. If the scallop strikes the side of the aquarium with any other portion of its body it does not have the power or perhaps the intelligence to swing the body around so that the foot will strike the glass. This observation shows that the scallop of 2 millimeters and over gains its position on the sides of the aquarium as frequently by swimming as by the more laborious method of crawling up the sides.

Value of the Attachment. — The value of the byssus as a protective factor is at once apparent when one considers the rough conditions to

which the scallop is often subjected. If it were not for some means of holding fast to the eel grass or other supports, the heavy storms would wash the small animals ashore. So possibly this power has been developed by natural selection for the protection of the scallop. Also, nature has acted wisely in making the attachment and climbing powers of the scallop supplementary, as the climbing habit is necessary to enable the scallop to reach a place of attachment, or, when attached, to find a better location.

Spat Collecting. — The attachment period in the life of the scallop naturally offers the best opportunity for the capture of "seed." When this period of life is reached in the case of the oyster, the planter puts into the water large quantities of shells, on which the young oyster may "set" or permanently attach itself by a calcareous fixation. The scallop, unlike the oyster, has no power of calcareous fixation, and the byssus is not a permanent attachment. If found desirable, old nets, frayed rope, boxes, etc., hung in a moderate current, should furnish an excellent means of collecting spat. Although scallop larvæ were plentiful in the water, no natural set on the eel grass occurred during the summer of 1906 in the Powder Hole at Monomoy Point. Nevertheless, on boxes and frayed rope, lowered for spat collecting from a raft, 1,200 small scallops were obtained in a few square feet of surface. At the present time there is no distinct need of spat collecting, as "seed" is superabundant in many localities. The young dissoconch scallops usually are attached by one byssal thread.

LOCOMOTION.

The young scallop depends greatly upon its powers of locomotion to enable it to maintain the struggle for existence, to seek new fields and to escape its enemies. Early movement is shown by the swimming of the ciliated embryo, an entirely distinct process from the same function in the adult scallop. Between intervals of attachment it moves by crawling with the foot either along the level or clinging to perpendicular surfaces, a considerably slower method than the earlier habit. Later, the swimming powers of the adult gradually appear, although the scallop still maintains its crawling powers. There is a gradual development in its methods of locomotion comparable to changes in its life, each of which are adapted to the special needs of the animal.

Crawling. — The scallop, long before it lost the faculty of swimming with its foot, had the power of crawling, although it did not wholly rely upon this method. When the body became too heavy to swim successfully with the foot, the animal depended entirely upon the latter means of locomotion. Later, when the swimming habits of the adult made their appearance, the young scallop used both, assisting the act of crawling by shooting a stream of water from the posterior edge of the shell in unison with the contraction of the foot. Crawling is accomplished by three muscular actions of the foot, extension, holding and contraction

(Figs. 55-57). Before starting to move the scallop projects its foot, waving it several times around, as if to reconnoiter. Then, suddenly becoming bold it stretches out this organ in a decided manner. The foot is elongated about the length of the body by the contraction of the circular muscles, which is called a "thinning wave" by the German. The free end is firmly set by a sucker-like arrangement, and a "thickening wave," caused by the contraction of the longitudinal muscles, passes toward the shell. The foot movement is roughly comparable to the creeping of an earthworm. The shortening of the foot jerks the shell forward, the movement being strengthened by the clapping of the valves, which send out a current of water posteriorly from the pseudo-siphon, as is indicated by the moving specks of dirt in the water. The valves shut when the longitudinal muscles contract and open with the contraction of the circular muscles, giving a jerky motion to the crawling.

The scallop may change its direction in crawling by setting the tip of the foot to either side of the line of motion. When the foot contracts the shell is swung around very effectively. As the animal has never been observed to crawl backward, a frequent maneuver with young clams and quahaugs of this age, it probably reverses its direction by a series of these movements. The animal often changes its base of crawling from the face of the right valve to the free edges of both valves. In this case the valves are so tilted that the posterior portion of the free edge is uppermost, thus making the anterior posterior axis perpendicular to the surface on which it crawls. (The above observations were made on 1 to 2 millimeter scallops.)

An early dissoconch scallop (phase 4) was observed to take a peculiar position on the bottom of a watch glass. It raised itself on to the edge of the shell with the anterior end high in the water, the foot extended, waving back and forth. Whether it did this by other aid than the lashing of its foot could not be ascertained, but it gracefully rose on edge. A similar maneuver was observed in a $1\frac{1}{2}$ -millimeter scallop. Evidently this habit is useful in turning over when the young scallop finds itself on the wrong valve.

In a young scallop about 1 millimeter in size (phase 5) the following rate of traveling was observed. The heart beats faster when the scallop is crawling than when the animal is resting. Occasionally all visible cardiac movement ceases for short periods during the resting stage. The rate of beat when crawling is about 100, when resting 85, per minute. The first series of continuous movements permitted the animal to cover the space of 5 millimeters in thirty seconds. On a second trial the scallop was able to cover the same distance in twenty seconds, taking six movements. Taking an approximate average the scallop would be able to cover 1 inch in two minutes, or thirty times its length, if it traveled consecutively.

The crawling stage can be divided into three periods: (1) swimming

and crawling by means of the foot with its ciliated tip; (2) the true crawling stage, where locomotion is by means of the foot; this is found only in the early dissoconch scallop and is of short duration; (3) crawling with the foot and swimming by a clapping of the valves, as in the adult. The actual use of the foot for crawling covers a long period, as the animal continues to creep more or less until it reaches a size of $1\frac{1}{4}$ inches, when the foot becomes too small for this purpose.

Climbing.—Climbing rather than horizontal crawling seems to be the natural instinct of the young scallop, which seems to prefer going up the sides of an aquarium to crawling over the bottom. Young scallops 0.6 to 0.8 of a millimeter, placed in a glass dish, climb up the sides until they find a place for attachment by the byssus, crawling over or around obstacles with equal readiness. A needle was placed before a crawling scallop, and it climbed up this for several millimeters before it found a resting place. The usual point of attachment is just below the surface, but the scallop may encase itself in a drop of water somewhat above this level. The scallops do not climb out of the water, as evidently the siphon helps the foot in the work of climbing and it is impossible for the animals to lift the increased weight of the body.

Scallops do not progress with such rapidity as in crawling, as the animal is forced to support its weight when making each extension of the foot. In the larger scallops the action of the foot is aided by the tentacles, which at times seem to offer support as the animal rests against the sides of the glass dish. The pseudo-siphon on the posterior side of the mantle aids by forcing a jet of water from the shell at the same time that the foot contracts. Evidently the scallop maintains its position for the most part by means of the foot, which makes a double bend so that a second part near the byssal gland touches the surface. Possibly by using this portion as an elbow, in the same manner as when the byssus is formed, it is able to cling to the support. Ordinarily the lift comes directly upon the end of the foot, as scallops have been observed hanging on the sides of the dish by merely the tip, and to pull themselves up by the contraction of the foot alone. Part of the contracted foot then rests on the glass, and the distal end lengthens out, searching for another resting place.

It was observed that 25-millimeter (1-inch) scallops could climb for a distance of 4 to 5 inches on a smooth, perpendicular surface. The larger scallops were not so active as the smaller, and the 25-millimeter size seems to mark the end of the climbing activity of the animal, the foot evidently being unable to support the heavier body.

The use of the climbing power is connected with the attachment of the scallop. Whenever the animal is shaken from its point of location it can climb back to another perch on the eel grass. There seems no selection in the climbing instinct, only a tendency to mount upwards. It is also possible, when the set strikes the eel grass, that the scallops

may have to climb to get their proper positions. If it were not for the ability to climb upon the eel grass again, many detached scallops would undoubtedly perish.

Turning Over.—The young scallop (Figs. 49–51) possesses several resources by which it may orient itself when placed on its upper valve. There are two general means, one by help of the foot and the other by the clapping of the valves. With the small scallop the use of the worm-like foot is the primitive method of getting into a natural position. When scallops from 1 to 1½ millimeters are placed on their left valve, they at first appear uneasy. After a few moments the animal thrusts out its foot, waves it around as if seeking a foothold, and finally applies the cleft tip to the bottom of the glass dish with a twisting motion. By this movement the shell is pulled so that the hinge line is resting on the bottom of the dish (Fig. 50), and the scallop pries itself over in the opposite direction, naturally falling into its right position. This operation is frequently aided by a slight opening and shutting of the valves. The quickest way of turning over in case of the older scallops is by clapping the valves, which flips the animal from one side to the other. The animal may turn in a lateral direction on the hinge, but the usual turn is anterior or posterior, either toward the foot or away from it. Another means is to swim with foot extended, usually landing proper side up.

Rate of Traveling.—Observations were made on the rate of traveling of 3-millimeter scallops, placed both on the right and left valves. Scallop A, resting in an unnatural position on the upper (left) valve, compared with scallop B, resting on the lower valve, did not exhibit as great speed or travel so great a distance. Although young scallops do not seem to be as uncomfortable as the old when placed on the left side, they do not move so rapidly as in a natural position. Out of 19 consecutive moves scallop B showed 11 greater and 7 less than scallop A, while one was the same distance. Scallop A traveled a total distance of 190 millimeters in thirty minutes, but actually gained only 37 millimeters, owing to its random movements. The same irregularity, in spite of its greater speed, which is accounted for by the foot having a more direct line of tension for the single left retractor when the animal lies on the right side, was noticed on scallop B. The animals may move for some time without going far, and may even return to the exact place of starting. The distribution of scallops at this age is probably determined more by wind and current than by any movements of the animal itself.

Swimming.—The first attempt at swimming occurs when the surface cells of the scallop embryo acquire cilia. The succession of rotary, circular and straight line movements of the larva have already been described for this period, and likewise for the early veliger, with its ciliated velum or swimming organ. Also, the change from the

swimming veliger to the larva which swims by a kicking motion of the foot has been given in chapter III.

The adult swimming characteristics appear at the beginning of the plicated stage, after the mantle has become specialized. During and just previous the scallop has passed through a stage in the evolution of swimming, which, though closely associated with crawling, is the bond that shows its relationship with other lamellibranchs, such as the clam and quahaug. It is the "pseudo-siphon stage," so named from an organ formed by the edge of the mantle on the posterior side of the animal. In crawling, water is ejected from this opening with sufficient force to throw the animal ahead. It is interesting to note that this movement is the first indication of swimming in the animal, and that it is comparable to similar conditions in the other shellfish, which have fully formed siphons in the adult. The description of the adaptability of the anatomical parts of *Pecten tennicostatus* (Mighels) for swimming, as given by Drew (1), applies equally well to *Pecten irradians*, and is here quoted:—

Pecten is one of the ablest swimmers among lamellibranchs. The whole structure of the animal is modified for this purpose. The valves have become rounded in outline, flattened and comparatively light. The anterior adductor muscle has been lost, and the posterior adductor muscle, which is very powerful, is situated near the middle of the body. The cartilage has become well developed, so the shell may be opened quickly when the muscle relaxes, and the hinge line is straight, so there may be no unnecessary strains in opening and closing the shell. Each gill is attached by one lamella only, so water in the temporary cloacal chamber may be thrown out without injuring the gills, and the gills and margins of the mantle are provided with muscles to withdraw them from the margins of the shell when the shell is closed. Furthermore, the margins of the mantle are provided with infolded ridges and with circular muscles, so it is possible to direct the current of water which issues from the shell in the required direction.

The only striking difference in the swimming of the young plicated scallop and the adult is the extension of the foot by the former, possibly a characteristic retained from the old method of swimming with the foot. In all the swimming of the young the foot is thrust out to its full extent, and possibly assists the animal through the water, either by its waving motion or by its cilia.

The following excellent account of the method of swimming of the adult *Pecten* is given by Jackson (4):—

It is best to study the swimming in young *Pecten*s some 3 centimeters high, as at that age it is more easily seen than in adults, and does not differ from what may be observed in them. Lying on the bottom, with tentacles extended, the scallop suddenly folds the guard tentacles back so that they lie closely against the outer border of the perpendicular mantle

wall. The valves are then closed by a quick action of the adductor muscle and water is forcibly expelled. The first water expelled is driven out posteriorly in the direction of the arrow A (Fig. 61), and if this were the only or the main direction in which a current is expelled the animal would by impact of water be impelled in the opposite direction or anteriorly; but the action of swimming is more complicated than this would indicate. When the valves have closed to a slight extent the borders of the two thick, perpendicular mantle walls come in contact and then no more water passes out as indicated by arrow A, but instead, during further closure of the valves, it is forcibly ejected from the lower border of one ear, where the mantle wall is low and thin, as indicated by the arrow B (Fig. 61).

The water expelled at the point B is the most forceful current and probably of the greatest volume; by its means the creature is impelled in the direction of the arrow C. The valves open quickly and clap again. The second time, as before, the first water is driven out posteriorly; but when the mantle walls come in contact, the direction of the excurrent water is again changed, and is forced out from the lower border of one ear, in the direction of the arrow D (Fig. 62); being the strongest current, it impels the animal in the direction of the arrow E. This striking difference is noted, viz., that at successive claps the water is driven out from alternate ears, first on one side and then on the other. The resultant action of the several currents and successive claps, illustrated in Figs. 61, 62, is, therefore, to drive the animal in the direction of the free borders of the valves, or posteriorly. It is due to the alternate expulsion of the water first from one ear and then from the other, as described, that the animal presents a succession of zigzag jerks in swimming. The direction of the current alternately to the two ears appears to be voluntary, as scallops can scuttle over the bottom of a dish in a sidelong direction by successively expelling the water at each clap from one and the same ear. The action of the first current of water expelled posteriorly, before the mantle walls come in contact, gives the animal an upward jerk, and it is in virtue of this jerk, combined with the momentum in a posterior direction, that it maintains its position on the surface of the water, and also the high angle to the surface which it presents in swimming. The current driven out posteriorly in the initial closure of the valves is so powerful that water may be squirted by adults to the height of five inches or more from the surface by this action.

A few additional observations upon the swimming habit may not be out of place. Scallops acquire the power of swimming at an early age, as they are able to swim in the manner described above soon after they attain 1 millimeter in size. The swimming habit is adopted when the scallop becomes less proficient in moving with the foot, owing to the increasing weight of its body.

Scallops are capable of movements in other directions than described in the above paragraph. Specimens 8 to 10 millimeters in size, when approached ventrally with the point of a pencil, snap their valves together and dart back in a dorsal direction, evidently to get away from the pencil, which they allow to get within reach of their tentacles before moving. The water is expelled with a quick squirt from the ventral

portion of the valves. The distance covered on the back dart was about 10 millimeters. This observation was made several times on different scallops, and is interesting, as it shows that the scallop can force water from different parts of its shell, in this case exactly at right angles to its usual direction. Darts can likewise be made in either an anterior or a posterior direction, showing that the body can be forced in any desired course by changing the point of expulsion of water from the shell. This habit is of a protective benefit to the animal, as the ordinary method of locomotion would be such as to carry it to an advancing enemy rather than allow its escape by a backward "shoot." This method is closely associated with the tactile functions of the tentacles, and it is only when stimulated that the scallop makes use of it.

RESTING.

The young scallops as well as the old have periods of rest, during which they probably feed or merely lie inactive. There are three kinds of rest: (1) the scallop attached by the byssus; (2) lying unattached on the bottom; (3) floating on the surface of the water.

Attachment.—This position has been defined under "Byssal Attachment," and only the appearance of the scallop needs description. The animal is probably in a feeding position, the mantle with its tentacles is extended, the heart beats slowly, and the food particles rotate in the digestive tract. In this position the animal is keenly sensitive to stimuli and if touched closes its valves at once.

Resting on the Bottom.—During the intervals of crawling the young scallops often rest on the bottom for a long time. Even in this resting position part of the internal anatomy is constantly moving. The cilia in the gills, in the digestive tract and on the foot are always lashing, while the foot is often restless and writhes within the shell. The tentacles are generally extended and the shell gapes slightly open. The heart action is less rapid than in crawling and at certain times seems to have ceased.

The natural resting position of the adult scallop is on the right valve on the bottom. Very seldom, and then only owing to accidental overturning, does it rest on the left valve. Often on a coarse sand bottom, especially in winter, the scallop excavates a shallow hole in the sand and lies passive, half concealed in its burrow. This habit may be protective in severe winters.

Drifting.—Scallops frequently drift just below the surface of the water, with the right valve uppermost, some with shells nearly closed, others with tentacles and foot extended (Fig. 47). The foot evidently needs to grasp some object before the animal can control the direction of the motion. If one of the drifting animals is jostled with a needle it sinks to the bottom, probably taking in a little water. Scallops as

large as 10 millimeters have this habit of floating, and scallops of 6 millimeters are often found with tentacles widely spread out. The reverse position of the animal, the right or lower valve being uppermost, is not so unnatural as may seem at first, as it can be likened to the crawling of a fly on the ceiling. The surface of the water acts as a wall upon which the scallop, with its extended foot, can rest. *Pecten* and *Anomia* have been observed apparently crawling, right valve up, on the surface of the water in the same manner as on the bottom, only in a reversed position, evidently in a similar manner to snails, by mucous secretion.

In the case of the small scallops, the tentacles, which appear to support the larger scallops, are not essential for floating. Very small dissoconch scallops, before the formation of tentacles, have the floating habit, and do not depend, therefore, on the tentacles to support them. The habit of floating is useful in that it probably allows the scallop the opportunity to get a better supply of oxygen, and to be carried from one locality to another or from one stalk of eel grass to the next by the current.

MIGRATION.

Many remarkable stories concerning the movement and migratory habits of the common shallow-water scallop have long circulated among the fishermen. Several writers have described schools of scallops in the act of skipping and swimming over the surface of the water, and have attributed to this species the migratory powers of fish. Scallops are reported to traverse many miles, passing from one part of the coast to another, continually on the move. Unfortunately, these stories have arisen from incomplete observations, which, supplemented by the use of the imagination, have credited the scallop with powers it never possessed. Indeed, so much has been said concerning the swimming powers of the scallop that people have come to believe that the scallop should be considered as a migratory fish.

While the basis of these reports is correct, there has been much exaggeration. The scallop has the power of migration only in a limited sense, and although capable of swimming never traverses far. In a small bay or harbor it is possible for the scallop to move to various parts, especially if there is a strong current, but extended and definite movements never occur. Swimming is a frequent diversion of the scallop, which, after lying quietly on the bottom, suddenly takes a slanting "shoot" through the water. The scallop is not built for continuous traveling, as it seems to need periods of rest between each flight. The average distance covered in a single movement is about 10 feet, while often it is much less. The longest flight ever noticed by the writer was about 25 feet, which is an exceptionally long distance for the scallop to traverse at one time. Occasionally a series follow in quick

succession, but more often many hours elapse between them. As the scallop is incapable of making continued flights for any distance its migratory movements, if such it has, are limited to certain definite areas, and never extend over a large territory.

A swimming habit of the scallop, which undoubtedly gave rise to the mistaken idea that they swam in schools on the surface of the water, can be observed particularly toward evening, when the scallops in the shallow water rise to the surface, shoot a jet of water in the air, and then, closing their shells, sink to the bottom. This fact has given rise to another popular fallacy, that the scallop has to come to the surface to breathe. The real explanation of this peculiar habit lies in the swimming of the scallop. In swimming water is taken in by opening the valves, and is then ejected on either side of the hinge line. The scallop, in traveling through the water, is forced to take an upward slant to keep moving, and in shallow water the animal soon rises to the surface. Not being able to take in any more water by opening its valves, the animal gives one final squirt, and sinks to the bottom with closed shell. This strange habit of the scallop is readily explained as the natural result of the sudden ending of its swimming.

The idea that the scallop makes a definite migration from shallow to deep water during the warm months of the summer, and returns to the shallow water in the fall, has spread widely. Where this idea could have arisen is impossible to state, but it has always been considered as an established fact. As far as could be discovered by the experiments and observations, the idea is wholly erroneous. Scallops have never been seen to make any such definite migration during the summer, and monthly records have been kept of scallops in the shallow water in as many as fifteen localities in the State, with the result that no movement of any kind was observed during the whole season. Not only were observations made for one year, but for a period of three consecutive years, which seems to conclusively indicate that no such migration ever takes place.

There are several possibilities for the irregular movements of the scallop, and the element of chance has a great deal to do with its traveling. If a bed of scallops happens to be in a swift current the scallops may be carried along by the strength of the current, whenever the animals rise in the water. As this is usually a tidal current the distance traveled is not far, and the opposite tide washes them back to the starting place. The scallops in a heavy wind are rolled along the bottom and in this manner are carried some distance. This method of migration likewise depends on chance, and is only applicable to scallops in shallow water, where they are unprotected by eel grass. Many scallops are yearly washed ashore, which is sure indication of the force of the waves and helplessness of this bivalve. Undoubtedly this is the most extensive means of traveling, and is probably the only

one of importance. A third method of migration is possible when the young scallops are attached to eel grass by slender byssal threads. When the eel grass is torn up the young scallops drift with the wind and tide for long distances. In this way localities that have not had scallops for years can again be restocked, Ingersoll (8).

The scallop is short lived, very few ever reaching the two-year limit. The majority, therefore, have only one spawning season. If any adverse natural condition, such as a severe winter, kills off the small "seed" scallops for that year, the total crop for the following year will be exterminated, as it is a case where there is only one set of scallops spawning at a time, and generations so follow generations that all the scallops which are to furnish the spawn belong to the same set. In this way the scallop crop of any locality is often wholly exterminated, and it takes years before it can again assume its former proportions. Thus the uncertainty of the scallop crop makes it appear that the scallops migrate from one town to another, as one town will have an abundance one year, perhaps followed by a poor season, while the reverse may be true for neighboring towns. So what has apparently been considered a migration is in reality no migration at all, but is merely due to the short life of this interesting mollusk.

There are several facts that substantiate the non-migration of the scallop. While none can be termed actual proof, nevertheless they furnish strong evidence that the scallop as a rule does not travel far from its native place. It was found almost impossible to obtain definite data on the movement of the scallops, as there was no accurate way in which to observe them in their native haunts. One attempt was made which gave results of negative quality. About 400 tagged scallops were liberated in Nantucket harbor in such a location that they would have to cross the channel to get to the scalloping grounds. The scallops were tagged with copper wire through the "ear" of the shell, which did not hinder to any extent their movement, and were liberated in October, at the beginning of the scallop season. Careful watch was kept by the scallopers on the fishing grounds, but none were ever found, indicating that they had not traveled. They were so located that the least traveling would have carried them to some part of the scalloping territory. The possible errors were: too few scallops, interference of the tags with the traveling and the possibility that they were carried to other places than the scalloping grounds, or that they were overlooked by the scallopers.

While there is much difference of opinion among the fishermen as to the movement of the scallop, the majority believe that there is little or no traveling, basing their claim on the fact that they find scallops in the same place the year round, and that the beds shift but little. New beds seem to spring up when the eel grass is rolled away, but the scallops probably have been there always, or have been carried a short

distance by either wind or tide, and have not come from miles away, as has been frequently supposed.

In all the observations made by the Massachusetts Department of Fisheries and Game on the habits of the scallop records have been kept of the different sets in many scalloping localities in the State, and no case of extended migration has been recorded. It has been impossible to make as extended observations in the deep water as in the shallow, but there is every reason to believe that the same conditions hold true, in spite of the fact that the scallops can more frequently be carried by the current.

A further fact of interest in this connection is the distinction between the two sizes of scallops, the large channel or deep-water scallop, and the small shallow-water or eel-grass variety. These two are the same species, but, owing to the better growing conditions in the deep water, the channel scallop is much larger in size. If the scallop were a migratory form, and would travel first to deep water and then to shallow, there would be no well-marked distinction between these two groups, as all scallops would be approximately the same size. This fact furnishes excellent proof that there is no such thing as definite migration.

In conclusion, the matter can best be summarized by stating that while the scallop is capable of swimming through the water by its own exertions, it can never travel any great distance in this way, and that there is no such thing as definite voluntary migrations. While no exact proof can be obtained there is not sufficient evidence to show that the scallop ever travels, and the weight of the evidence implies that there is never any migration. The only possible traveling of the scallop is caused by forces external to the animal, such as wind, current, storms, etc., and is merely a matter of chance. This cannot be styled in any sense a true migration, and there is little evidence to show that any considerable distance is traveled by this means.

The non-migratory habit of the scallop is of importance to the scallop planter if in the course of future events cultural methods are ever applied. It is also of great importance to the town, as no town may feel that their scallop crop will travel to the borders of the neighboring township. The scalloping towns can rest assured that, if the scallop crop is once within their borders, there is slight chance that it will ever leave.

RECOVERY FROM INJURY.

Scallops are frequently found with twisted and warped shells, or other deformities. Jackson (4) reports finding scallops with portions of the mantle missing, evidently from the attacks of predacious fish. Occasionally small fish about 1 inch in length are found within the scallop shell. In many of the growth experiments, where the scallops were kept in confinement in wire baskets, the growth was abnormal, as the shell grew in a variety of shapes, owing to the manner of resting

against the wire. To observe their recovery from injury, scallops were treated in a variety of ways: (1) four scallops were unhinged by breaking the ligament; in three days' time three were dead, one was alive; (2) small holes were bored in shells of three scallops: all were dead in three days; (3) five with adductor muscle badly strained: in three days two were dead, three alive; (4) three with valves cracked lengthwise: in three days one was alive, two were dead; (5) one with valve cracked along byssal groove: alive two weeks later but shell not mended; (6) three with small piece cut out of mantle edge; in three days two were alive, one was dead. The result of these mutilations shows that the scallop, although not as hardy as the clam or quahaug, is capable of repairing minor injuries inflicted by enemies, and only succumbs to the more severe hurts.

FEEDING HABITS.

The feeding habits of the scallop are similar in many respects to those of the other shellfish, as all lamellibranchs obtain their food by means of the gills, which act as filters or strainers. The clam and quahaug lie beneath the surface of the soil and reach the water by a fleshy extension of the mantle, known as the siphon. The scallop has no siphon and its method of life is such that it does not need an organ of this nature. When in a natural position for feeding, the animal rests on the bottom on its right valve, the shell gaping open at an angle of about 20°. Closely lining the inside of the two valves is a thin fleshy substance, the mantle, described in chapter II. When extended, the edge, lined with papillose tentacles and brightly colored eyes, passes beyond the shell, while another portion, consisting of a perpendicular flap, surmounted with a row of closely set guard tentacles, acts as a curtain to nearly close the intervening space between the open valves. Instead of the specialized siphon of the clam, which is in reality only a part of the mantle, the scallop makes use of the entire ventral area of this fold to take in its food, with the result that a continual stream is passing in through the mantle and going out at a definite locality in the posterior side of the shell. This portion of the mantle is destitute of guard tentacles, and, when the walls are closed together, forms a pseudo-siphon.

The food of the animal, as more fully described in the report on the food of the lamellibranchiate mollusks, consists largely of certain microscopic plants, called *diatoms*. These tiny forms are extremely varied in size and shape. They are easily recognized by their silicious cases and beautiful markings, which have won for them the name of "the jewels of the plant world." They are found in the water everywhere in more or less abundance, and are filtered out by the scallop from the water which bathes its gills.

The four gills, which were described in chapter II., in addition to aëration of the blood possess the important function of straining food

from the water. Lying free in the body cavity, they are constantly surrounded by the flowing water, which passes through and around the filamentous bars. When examined under a microscope the gills are found to be covered by small hair-like cilia, lashing in a definite direction. These cilia cause currents of water to pass over and through the gills, while other cilia between the filaments act as minute sieves to strain out the food particles, which are at once cemented together with a mucus and propelled by the ciliary action toward the popularly called "backbone" of the gills, or the dorsal edge. Here they are taken up in a more definite channel and swept with increasing velocity toward the upper end of the gills to the lower edges of the palps. The palps are ridged and furrowed like the gills, and the food is transferred to the mouth by means of these "lips." If an excess of food or foreign matter is caught by the gills, the animal, by a complicated mechanism, as described by Kellogg (3), is able to cast it off.

The effete matter from the digestive tract is carried out from the shell at the posterior pseudo-siphon. The waste in transverse section has the appearance of a three-leafed clover, Jackson (4), and is of uniform length. When the scallop lies feeding in the aquarium, the feces pass out at regular intervals of about a minute, suggesting a nearly constant need of food. The constant flow of water through the shell shows that the other parts, such as mantle, visceral mass, etc., must likewise be ciliated as well as the gills, in order to force the flow of water in one direction, an entirely different arrangement from the ejection of water by the mantle in swimming.

SENSORY POWERS.

The exact reactions of the scallop to light and other external stimuli have never been worked out, and there remains a wide field for investigation on these points, especially in regard to the effect of light. The following are a few meager observations which it is hoped may interest some one to take up the study of the sensory powers of the scallop.

The scallop is sensitive to a sharp tap or sudden jar. When small 6-millimeter scallops are attached to the sides of glass dishes, the valves remain open, tentacles extended. A sharp tap on the outside of the jar directly over the animal causes it to retract its tentacles, but after repeated tapping the creature does not seem in the least disturbed, as the tentacles remain extended. All motions outside the glass dish were unnoticed by the scallop.

At times the adult scallop is quite sensitive; again, the same stimulus does not excite the animal. Evidently it has various moods. Jackson (4) states that when spinning the byssus the scallop appears undisturbed by pricks, etc. As cold weather comes on the animal becomes less active and fails to respond with its former alertness.

The eyesight of the animal has aroused considerable comment. The

eyes, so far as concerns the gross anatomy, closely resemble those of the higher animals, and are connected to the circumpallial nerve by short nerve fibers. To what extent the animal can see is a question. Observers have stated that scallops lying on the eel grass notice a person wading through the water and swim off. Whether this is due to sight or to the disturbance of the water is uncertain. It is true that movements in the water have more effect than those outside, and the effect of shadows on the scallop may cause it to withdraw its tentacles. The approach of enemies is readily recognized by the scallop, which scuttles out of harm's way. Whether this is from sight or other modes of sensation is as yet undetermined.

Veliger scallops apparently are not sensitive either to dark or light. With scallops of 2 millimeters and over, in which the eyes or tentacles are developed, different results were obtained. A few tests were made with animals of this size in small dishes, covered with black paper, except in certain places for the admission of light at the will of the operator. Many of the results were negative, but a slight heliotropic (toward light) tendency was evidenced.

The young scallop under 3 millimeters evidences little preference for different colors. Tests along this line have given negative results, as the distribution on areas of different color seemed at random.

Scallops will live in waters that have a density of 1.010 or greater, one-half salt to one-half fresh. This has been tested by observations in different localities and by keeping the animals in aquaria with various densities. The scallop, compared with the clam and quahaug, succumbs more readily. In aquaria, where these burrowing mollusks will live indefinitely, it is often difficult even with running water to keep the scallop alive for more than two to three weeks.

ENEMIES.

Owing to its free life and activity the scallop is beset by relatively few enemies, as compared with the oyster, or, more properly speaking, suffers less destruction from the same adversaries. Nevertheless, there are certain species which prove dangerous and cause the scallop a continual struggle to maintain its existence. Naturally in the early life of the scallop the destruction is much greater, and it is necessary to divide the enemies of the animal into two classes: those which menace (1) early life; (2) adult.

Enemies of the Young Scallop.— In the early life of the young scallop it is not so much the active animal enemies as the adverse natural conditions that destroy the embryonic larvæ. When the fact that only one of the several million eggs liberated by the adult spawning scallop ever reaches maturity is considered, the extent of the destructive powers of nature becomes strikingly manifest. The early life of the animal is the critical period of its existence, and it is at this point that the young

must be shielded from their enemies. The active enemies of the young larvæ can be enumerated: fish, other shellfish and animals of similar nature which suck down the larva for food, the adult scallop often treating her young in this manner. Later in life, when the young scallop is discernible to the naked eye, the starfish, crabs, sea fowl and other predacious animals feed upon it. Scallops of nearly 1½ inches in size have been taken from the crop of an eider duck by John H. Hardy, Jr., of Chatham.

But the force which causes the vast destruction is not accounted for by these active enemies. It is broader and farther reaching in its influence. It is nature, with her vast adverse conditions. Severe weather, storms, sudden changes in temperature and in salinity of the water during the spawning season, sewage and other contamination, may bring about the destruction of the floating larvæ. The localities of set are such that only a limited area is available for the retention of the spat. Eel-grass-covered flats are best adapted for the set, and other localities generally prove unfruitful. The larvæ, uniformly scattered through the water, are washed hither and thither, relatively few ever setting on good ground, the rest either washing ashore or being buried on slimy and unwholesome bottom. Thus the infant mortality is especially great and only a very few escape the perils of the embryonic stage of their existence. These few are now at the mercy of the elements until they have attained sufficient size to enable them to take care of themselves. On the eel grass they are constantly in the danger of washing ashore. When the set is on shallow flats, for example, the Common Flats of Chatham, the scallops are nearly exposed at low running tides, and thus often are killed by the severe winter frosts and ice. Even when in deeper water, the "anchor frost" is said to destroy them in great numbers, but fortunately this condition is rarely found.

Enemies of the Adult.—The adult scallop has several natural enemies, including man, both active and passive, as well as being subject to the adversities of nature, for the scallop, by reason of its specialized anatomy, is most susceptible of all economic mollusks and readily succumbs to an unfavorable environment.

(a) *The Starfish.*—The starfish (*Asterias forbesii*) is probably the most destructive pest of the scallop fishery, and has proved a source of great annoyance and loss to the scallopers. Fortunately the inroads of this pest are chiefly confined to one section of the State, Buzzard's Bay, and although the animal is found in some abundance along the south side of Cape Cod and at the islands of Nantucket and Martha's Vineyard, it is not so serious a menace to the industry. Many of the Buzzard's Bay fishermen attribute the decline of the scallop fishery in those waters some eight years ago to the invasion of the great numbers of starfish at that time. From reports by the fishermen the scalloping grounds were literally paved with starfish, and it was utterly

impossible for the scallops to escape destruction. It is well known how destructive the starfish is to the oyster beds, and undoubtedly the scallops would not be able to escape so great a number and must have suffered severely. Capt. James Monahan of Wareham cites the following instance: "In the fall of 1898 I located a bed of seed scallops so thick that half a dredge full could be obtained at a single drift. Next year I went to the same place, and on casting my dredges found them full of dead scallops, shells and starfish in great number." He estimated that in that one locality 1,000 bushels perished.

During the season of 1907-08 nearly every boat from Wareham saved the starfish, and instead of throwing them overboard, as was previously the custom, carried large numbers to the shore. Under the old method of carelessly returning these pests to the waters they were scattered over a wider area from the boats. For two seasons previous to 1907-08 it is said that the starfish had been decreasing, and that the return of the scallop fishery after an absence of seven years was due to this decline. Many scallopers and oystermen are anxious for State appropriations for the removal of these pests.

The method of attacking the scallop (Fig. 70) is similar to that used on the oyster, *i.e.*, opening the shell by means of a steady strain exerted in opposite directions upon the two valves. The starfish surrounds the scallop with its long arms or rays, five in number, and clasps it in its embrace, generally in such a way that the mouth of the starfish rests just above the byssal notch of the scallop, and the arms are closely attached to the shell by the tube feet or suckers. By exerting a steady pull with its numerous suckers, and by the tendency to straighten out the long arms, the animal exerts a strong and steady strain on the adductor muscle, which, though well adapted to resist a sudden pull, gradually tires and relaxes. The starfish has the advantage, as, having five arms, it can rest some of them and yet keep on pulling, while the scallop has only one muscle and has to exert a perpetual strain. Then a curious phenomenon is noticed. The starfish rolls out its stomach and allows it to flow into the interior of the scallop, where it digests, outside its own body, the soft parts of the scallop. When the meal is completed the stomach is withdrawn, and the clean scallop shell left with gaping valves.

Small starfish seem to be the most active in this work of destruction, and the "seed" scallops are the most frequent objects of their attack. The only method of reducing this pest, as extermination is practically impossible, is for the scallopers to carry the starfish taken in dredging to the shore. The oystermen, who suffer more severely from the inroads of the starfish, most commonly use a tangle or mop which is dragged over the oyster beds, the "five finger" becoming easily entangled. The starfish are then either thrown into boiling water or carried ashore.

(b) *The Oyster Drill*.—Where the scallop is not found the oyster

drill (*Urosalpinx cinerea*) (Fig. 68) is generally present. This little gasteropod mollusk, next to the starfish, is the most destructive enemy of the scallop and oyster, and is found in nearly every scalloping locality. Scarcely more than an inch in height and of an innocent grey color it has proved a source of trouble to the oysterman, owing to the impossibility of thoroughly removing it from the oyster beds.

Its method of attack is to crawl upon the upper valve of the scallop and then pierce a hole in the thin shell, scarcely larger in diameter than a needle, by means of a tiny ribbon-like tongue armed with fine teeth. When the boring is completed the animal sucks out the contents of the shell. Scallops have been found destroyed by the drill bearing on the shell a row of globular egg cases which the drill had deposited. It is during this process that the scallop has an advantage over the oyster. The latter is fixed and immovable, the former is capable of movement, and by a few well-directed flaps of the shell can in many instances throw off the intruder and escape destruction. The numerous half punctures in many living scallops bear witness to the inability of the "borer" to finish its task.

A few observations upon the length of time it takes to bore and eat a scallop were made at Monomoy Point with a view of determining the actual extent of destruction. Scallops were confined with the drills in boxes with netting tops. Different numbers of scallops and drills were used for over a month. As many as five drills have been found on one scallop not in confinement, and as many as two or three are of common occurrence (Fig. 95). The conclusion arrived at from these observations was that it took from four to six days for the drill to pierce the shell sufficiently to eat the contents, and that the meal was consumed in about the same amount of time. At this rate the drill could only eat about three large scallops per month, even if nothing interfered with the operation, and in the long run the amount of destruction would be extremely slight. While the unnatural condition of the confined animals may have made the process slow, the limited area afforded the scallop but slight chance to escape from its enemy and so partially offsets any error.

(c) *Nassa obsoleta*. — The third active enemy of the scallop is perhaps hardly to be classed under that head. It is the scavenger of the tidal flats, the little black winkel, *Nassa obsoleta*, which has the important duty of cleaning the flats. The actual damage done by this animal is comparatively small, as it is not an inhabitant of the same localities as the scallop as a rule, being found between the tide lines. *Nassa* is commonly thought to be of little damage to living shellfish, though it is known to eagerly devour any dead or broken specimens. Although the damage is of little account the method of attack is so interesting that it will bear relating. The scallop when resting on the bottom with tentacles extended is at times extremely sensitive, and then

again less so. *Nassa* possesses an extremely well-developed sense for finding food and gathers around the scallop in numbers. Then a concerted action takes place, whether intentional or by accident, but it occurs time and time again. One *Nassa* forces itself between the valves of the unwary scallop, which at once close with a snap, but only part way, as the little winkel has formed a wedge between the valves which permits the entrance of more of its kind, which rapidly fall to eating the contents (Fig. 94). While we cannot attribute this mode of attack to any reasoning powers of the small creatures, the fact remains that 17 out of 500 scallops, confined in a pen 10 feet square, in two weeks' time were killed in this way. However, under natural conditions this would be impossible in the open. The scallops were observed continually to flirt off the crawling *Nassa* by snapping the valves, and in this way were able to protect themselves.

(*d*) *Passive Enemies*.—The scallop has besides these active enemies other passive foes which perhaps do not accomplish so much apparent damage but affect the growth of the animal and in some cases result in its death. Such are the enemies which use the same food and retard the growth by depriving the scallop of sufficient nourishment. All other shellfish, both valuable and of no importance, come under this head. Another class of passive enemies are the ectoparasites on the scallop shell, the sea weeds, such as *Enteromorpha*, *Ulva lactuca*, etc., barnacles, *Serpula* (worm tubes), *Anomia*, *Crepidula*, oysters from one to two years old, *Acmaea*, etc., which not only partake of the same food but hinder the movement through the water, and in cases like the oyster and *Serpula*, by their growth in time kill the scallop, in the case of the former by weight of shell, with the latter by binding edges of the valves together.

(*e*) *Man*.—While the main cause of the decline of the natural clam, quahaug and oyster beds is overfishing by man, the decline of the scallop fishery cannot be so considered. The scallop has a short life, hardly 25 per cent. passing the two-year limit; so it does no harm to capture the marketable scallops which are over sixteen months old, as the scallop spawns when one year old and dies a natural death usually before it reaches a second spawning season. When only old scallops are taken, as is generally the case, it is probably *impossible* for man to exterminate the scallops by *overfishing*. Unfortunately, in certain localities in the past there has been a large capture of the "seed" scallop, viz., the scallop less than one year old, which has not spawned. This has worked the ruin of the scalloping in these localities. The capture of the spawners for another year merely makes the next year's set so much smaller, and causes a rapid decline.

As a rule, it is hardly profitable to catch the "seed" scallop, owing to its small size. But a direct relation can be established between a high market price and the capture of seed. When the market price is

high and scallops are scarce, it becomes profitable to catch the young "seed." The present scallop law now defines a "seed" scallop and forbids its capture. By protecting the "seed" scallop, the State has done all that at present appears expedient to insure the future of the industry; the rest lies in the hands of the towns.

So, while the scallop has declined in certain localities, and the decline has been hastened by unwise capture of the "seed" scallop, the main decline of the fishery cannot be attributed to wholesale overfishing, as it is impossible to overfish if only the old scallops (over one year old) are taken; for, unlike most other animals, the scallop usually breeds but once, and its natural period of life is unusually brief. These scallops, if not taken, will die, and prove a total loss; so every fisherman should bear in mind that, as long as the "seed" scallops are protected, severe fishing of large scallops is not likely to injure the future scallop industry.

The adult scallop has to contend against the same adverse physical conditions of nature that beset the young animal. Severe winters, storms, anchor frosts, etc., work destruction upon the helpless scallop. Exposure to low tides, as on the Common Flats of Chatham, and on the north side of Cape Cod; exposure to sewage contamination, as in New Bedford harbor; exposure on an open coast, as is occasionally the case on the south side of Cape Cod; sudden changes in the salinity of the water, *i.e.*, by flood waters; the distribution of tides and currents; the temperature of the water; the nature of the bottom, — all affect the life of this mollusk, and render its existence precarious.

The very nature of the scallop's period of life renders it peculiarly sensitive to adverse conditions, and places difficulties in the way of its natural propagation.

As the scallop dies before reaching its second birthday, only one set of scallops spawn in any one season. There are never two generations of scallops spawning at one time. I quote from Ingersoll (8) in this connection: —

This represents a case where the generations follow one another so rapidly that there are never two ranks, or generations, in condition to reproduce their kind at once, except in rare individual instances, since all, or nearly all, of the old ones die before the young ones have grown old enough to spawn. If such a state of affairs exists, of course any sudden catastrophe, such as a great and cold storm during the winter, or the covering of the water where they lie for a long period with a sheet of ice, happening to kill all the tender young (and old ones, too, often) in a particular district, will exterminate the breed there; since, even if the older and tougher ones survive this shock, they will not live long enough, or, at any rate, will be unable to spawn again, and so start a new generation.

The set of young scallops is abundant in shallow water upon the eel-grass flats, which often, as is the case of the Common Flats at Chat-

ham, are exposed at extremely low tides. A severe winter often kills off all the "seed" thus exposed. In this case no spawn is obtained the following summer, causing the suppression of the scallop fishery in that locality for at least a few years, and possibly its permanent extinction.

The low temperature during the winter, particularly in the shallow waters and on the exposed flats, is often destructive to the adult. Scallops have been observed in zero weather frozen, with shells full of ice, as they lay on the exposed flats at Parker River, Yarmouth. Undoubtedly many die, but many recover from being frozen, as shellfish will live if properly thawed out. In the severe winter of 1904-05 the entire crop of scallops was killed on the Common Flats, Chatham, and in 1906-07, 40 per cent. of the "seed" on the Stage Harbor flats, Chatham, succumbed to the ice and cold. Often the ice settling on the flats carries with it the scallops, or leaves them in a dying condition. Low temperatures, tides and currents work together, as the scallop, rendered inactive by the coolness of the water, is at the mercy of the elements, and is readily washed ashore, to perish on the open beaches or high flats.

POPULAR FALLACIES.

Many interesting but erroneous ideas concerning the habits of the scallop have arisen among the fishermen, and a brief mention of several will bring this chapter to a fitting close. The length of life of the scallop has always been a perplexing question. While the majority of the scallopers have drawn correct conclusions from their practical observations, a few still maintain that this mollusk lives for a long period of years. Arguments to this effect are based chiefly upon the foreign growth, which is abundant on the shells of the old scallops. Successive layers of *Crepidula* (quarter deckers or sweetmeats) piled one on top of the other on the shell are claimed to denote a yearly period for each new animal, and large barnacles, worm tubes, etc., are considered as indicating a long period of development, while in reality these bodies are the result of only a few months' actual growth.

The idea that it was necessary for the scallop to come at least once a day to the surface to breathe arose from seeing the animals rise in shallow water to the surface when swimming. Such a conception appears absurd when it is known that the scallop possesses gills like a fish and is not an air-breathing animal. Numerous misconceptions as to its migratory, swimming, attachment, feeding and other habits have prevailed during past years, and it is sincerely hoped that this chapter on habits may aid in clearing many misunderstandings about the life of the scallop.

CHAPTER V. — GROWTH.

The rate of growth of the scallop, besides being of popular interest among the fishermen, has an important bearing on the development of the fishery. Owing to its intimate connection with practical scallop culture, a detailed study of the rate of growth comprised a large part of the investigation. In addition to extending the knowledge of the fisherman and defining the proper relation of growth to protective legislation, several facts of biological interest have been brought out by the experiments, and although not at present of practical importance, they are likewise included for the benefit of persons interested in the study of the Mollusca.

In the determination of the average growth of any shellfish it is difficult to make definite statements, as the natural conditions, which influence development, are varied. The rate of growth for one body of water is different from the growth in other localities, unless the same conditions are present, instances of which occur but rarely in nature. This fact not only has rendered difficult the concise presentation of the subject, but also has necessitated a manifold duplication of the experimental work in order to satisfactorily cover the conditions in Massachusetts waters. Therefore, the reader must understand that the general figures given in the following pages do not hold true for individual localities and are but the averages for certain sections.

Methods of Investigation. — The natural conditions of the scallop grounds in Massachusetts are dissimilar to the Rhode Island waters, Buzzard's Bay being the only section at all approximating the conditions in Narragansett Bay. These differences will be brought out later by a comparison with the growth experiments of Risser (2) on the Narragansett Bay scallops. The variety of conditions presented in the different localities of Massachusetts necessitated an extensive series of experiments, covering the same ground and in several instances with results at variance with the observations of Risser.

The opportunities for solving the rate of growth of the scallop under a variety of natural conditions were especially favorable owing to the diversity of the different scallop grounds. The average rate of growth for the different sections in the State, as here presented, is the result of three years' continued observations on sets of scallops under various environments. Excellent facilities for detailed work on the growth and length of life for a period of four years were afforded at Monomoy Point in the nearly landlocked harbor, the Powder Hole, and a large share of the experimental observations, many of which could never have been obtained elsewhere, were made in this locality. Inclosed in a natural aquarium, the scallops could be followed from birth to death under conditions many of which were under the direct control of the operator.

The general work consisted of two parts: (1) at Monomoy Point on the scallops confined in the Powder Hole; (2) records of the growth of the different sets at different localities along the southern coast of the Commonwealth. The investigations were first started in July, 1905, and continued steadily through 1906 and 1907. Records were also maintained in several localities for 1908 and 1909, while the work at Monomoy Point was continuous for the whole period. During this time records of the complete sets of 1904 (second year), 1905, 1906, 1907, 1908 were made at Monomoy, and for the State in 1904, 1905 and 1906. Another division of the work of a different nature can be made: (1) experiments in artificial culture, where the scallops were confined in pens of wire netting at Monomoy, Marion, Monument Beach and Chatham; (2) records of the growth under natural conditions on the scallop grounds by measuring large numbers of scallops. A description of the methods of work, details of measuring, construction of pens, marking of scallops, etc., is given in chapter VII.

General Growth.—The shell or exo-skeleton of the scallop is commonly considered the growing part and any increase in its size indicates the development of the animal. New shell formation is the direct result of a previous corresponding growth in the soft parts, whereby an extension of the shell is necessitated. In the following experiments the shell has been considered as typifying the development of the body, and all measurements have been recorded on this basis. The quality of the meat and the fattening of the tissues, so important to dealer, are not considered under the subject of growth, but are discussed in connection with the "eye" in chapter VI.

Shell formation by the secretion of the thin mantle lining the inside of the shell has been described in chapter II. The shell is built almost entirely of lime salts (principally the carbonates), which is obtained in some unknown manner from the water. It appears that the amount of lime in solution in the water is an important factor in the rapidity of growth, but is not as essential as the nourishment of the soft parts by the microscopic food. The actual increase in the rate of growth by an excess of lime is but slight, as the shell formation naturally depends upon the growth of the soft parts, and the difference is only evidenced by the increased weight of the shell in localities rich in lime salts. The lime supply varies somewhat in the different localities, and its efficiency is largely dependent upon the circulation of water.

In considering the rate of growth the matter of food is of chief importance. Within limits the growth of any mollusk is directly proportional to the amount of food it consumes. Scallops situated in good feeding localities will grow much faster than those less fortunately located. The food as stated in chapter IV. consists of microscopic plant forms, called diatoms, which are uniformly distributed through the water. Naturally the abundance of diatoms in any locality and the

circulation of water or current are the two external factors in the development of the scallop.

Growth of Scallop compared with Other Economic Bivalve Mollusks.—The limited life and active habits of the scallop require a quick maturity and light shell, which make its growth the most rapid of the economic bivalves. Arranging these mollusks in order of rapidity of growth, scallop, clam, sea clam, oyster and quahaug, we find that they are likewise placed in respect to the weight of their shells, the lightest shell corresponding to the fastest growth. From this we can formulate the general rule that the growth of any shellfish is directly proportional to the weight of the shell, which not only seems to hold true for the different species, but is applicable to varieties of the same species; i.e., a thick-shelled clam grows more slowly than a thin "paper" shell variety.

Variations in Growth.—Many variations are found in the growth of scallops. In no two localities is the size identically the same, as can be seen by comparing Buzzard's Bay, Cape Cod and Island scallops. This variation may be called sectional, and can be attributed to the difference in environment, which also applies to local conditions. There is also variation in the sets, the average of one year differing from the succeeding or preceding years. The size of a scallop is due to two main factors: (1) its time of birth, either at the beginning or end of the two months' spawning season; (2) the conditions under which it lives, whether favorable or unfavorable for rapid growth. Primarily the environment and secondarily the time of the set determine in a great measure the life of this mollusk. There is another type, individual variation, which is important to consider in presenting the results of the growth experiments, as it proves that correct results can only be satisfactorily obtained by records of large numbers of scallops. Risser (2) remarks on the remarkable uniformity of the individuals of the set in Narragansett Bay. No such uniformity has been found under the more diverse conditions in Massachusetts waters, and in individuals of the same set, especially in the young scallop, variations as great as from $\frac{1}{2}$ inch to $2\frac{1}{2}$ inches have been found at the same time and place. Between these extremes all grades can be found converging toward the average. Even when scallops of the same size are confined in pens their growth varies, a fact that can only be attributed to the individual traits of the animal.

Growing Months.—Man passes through four arbitrary periods in life, childhood, youth, manhood and old age, attaining his actual stature during the first two, and only adding more flesh as the years pass. The scallop, on the other hand, continues to increase in size during the adult period, and in fact up to the time of its death has not lost the power of growth, although the shell formation in the old scallops is somewhat slower than in the younger specimens. But the scallop only

grows half the time, as all shell formation is accomplished during the summer months and no increase in size is found during the cold weather. This gives the scallop a resting time between the period of youth and adult, and again during its old age, as the average life of the animal is from twenty to twenty-six months.

In following the life of the scallop born in July, growth ceases during December and is again resumed May 1 of the following year, when the temperature of the water has reached 45° to 50°F. The same scallop ceases growth in the fall, usually in the latter part of November (slightly earlier than the young set of that year), when the water has again fallen below 45°. Thus, every scallop has two periods of growth, corresponding to the two summers of its existence, and two resting periods during the winters. The cause of this cessation of growth is explained under the topic "Effect of Temperature."

By monthly measurements of the scallops confined in pens at Monomoy Point during 1906, the relative value of each month was calculated and the variation in growth for different parts of the summer was determined. In the following table each month is given a numerical number, representing the gain per cent. for the month, the entire year being considered as 100 per cent. (Figs. 84, 85):—

MONTH.	Per Cent.	MONTH.	Per Cent.
January,	-	August,	20.39
February,	-	September,	20.08
March,	-	October,	18.94
April,	-	November,	2.15
May,	19.76	December,	-
June, ¹	8.33		100.00
July, ¹	10.35		

¹ Decrease in June and July due to spawning.

Length of Life.— Briefly stated, the normal life of the scallop is from twenty to twenty-six months, relatively few scallops passing the two-year limit.

Previous to 1906, when this problem was first satisfactorily solved by the commission, the question most often propounded by the practical scallop fisherman was, "How long does the scallop live?" In spite of the diversity of opinion, which credited the scallop with living anywhere from two to five years, the majority of the scallopers believed that two years marked the limit of its life, a view which coincided with the results of the investigation. Both Ingersoll (8) and Risser (2) agreed with this view, but were unable at the time of writing to furnish definite proofs. So it fell to our lot to obtain, through a series of observations

covering several years, the necessary data for the actual substantiation of the popular theory, and for the establishment of proper legislation for the fishery.

The method of work consisted primarily of continued observations on the sets of 1905, 1906 and 1907, following each from birth to death. The greater part of the work was done in connection with the growth experiments in the different scalloping areas, but more particularly with the scallops confined in the Powder Hole at Monomoy Point, where favorable opportunity was afforded for obtaining data on the life of the scallop. An inclosed, protected body of water, forming a natural aquarium of five acres, from which the scallops could not escape; unmolested, owing to its being leased by the State for scientific investigation; a natural scallop bed with all normal conditions, yet small enough for direct control and observation, — were all factors which rendered the Powder Hole of especial advantage for the solution of this problem. Three sets of scallops were closely followed from birth to death under natural conditions, free from many natural enemies and the interference of man, and practically unable to escape. Likewise, scallops were confined in wire pens for two successive seasons and the actual death-rate of the old and young scallops compared under the same conditions.

The life of the scallop can be arranged in four arbitrary stages: (1) embryonic life or babyhood, from the time the egg becomes a living organism until the animal attaches to the friendly blade of eel grass; (2) adolescence, or the period ending when it first spawns at the age of one year; (3) the adult period, from twelve to twenty months, during the later part of which it is ready for the market; (4) senility or old age, from twenty months until the animal dies.

This last period, that of senility, is the important factor in considering the length of life of the scallop, as it is the time of physical decline. Old age is marked in the scallop by (1) slower growth and a slight thickening in shell formation for those specimens which live over twenty-three months; (2) a degeneration in the large adductor muscle or "eye," shown by flabbiness and diminution in relative size; (3) an increasing amount of foreign growth on the shell. One or more of these signs may be absent in individual specimens, but all are true of the general type. Old scallops are more sensitive or susceptible to adverse conditions than the scallops a year younger, and perish under conditions which would be survived by the latter.

The period of senility has no definite beginning. Possibly the scallop is on the decline during its adult life, having reached its maximum at the spawning season, and then, having outlived its usefulness, awaits death. One of the fundamental principles of nature according to the old school, as applied to the lower animals, is that life exists only so far as it concerns the reproduction of the species, and that animals, such as the mayfly, live only until they reproduce, and then perish.

But with the scallop we have the interesting case of an animal which spawns but once and yet lives for nearly a second year, perishing just on the verge of another spawning season, — an exact contradiction to this principle. This apparent phenomenon might be explained in two ways: (1) that a few second-year scallops are useful, as they spawn twice; (2) that probably the shallow-water scallop (*P. irradians*) once had a longer life and more than one spawning season, as its cousin the giant scallop (*Pecten tenuicostatus* Mighels), and that the present *Pecten irradians* is a decadent species.

About the first of March the adult scallops begin to die, and this period, when the average scallop is twenty months old, is taken as the arbitrary beginning of the period of senescence. In the natural scallop beds the majority of the scallops are caught by this time, while the remainder sooner or later die a natural death, a large proportion perishing before May or before the twenty-second month. This fact is well known to scallopers who fish late in the season, and there have been striking instances of large beds suddenly perishing, as at Dennis in March and April, 1905. After May the length of life is variable, some scallops passing the two-year limit (July) and occasionally living until the following October and November (twenty-seven and twenty-eight months), but the majority of these die before the twenty-fourth month (July). Exact data upon this subject were obtained from scallops which had been under observation in wire pens at Monomoy Point for two years. Records of death-rate from old age show that, of 465 scallops alive May 1 (twenty-two months), 32 per cent. remained by July 10 (twenty-four months) and only 6 per cent. August 2. In July these scallops would have been two years old. Scallops one year old, confined under similar conditions, showed only a slight mortality.

It is, therefore, fair to assert that under natural conditions, when unmolested by the scallopers, but 20 per cent. reach the two-year mark, whereas on the scalloping grounds, unprotected both from nature and man, the percentage of old scallops which reach two years is much less than in the inclosed Powder Hole at Monomoy Point, and in all probability the total which pass the two-year limit is under 10 per cent. All rules have their exceptions, and frequently instances occur where scallops of twenty-eight months (recognizable from two growth lines and general appearance) are found. In every scalloping ground an occasional scallop of this age or older is dredged. More particularly, in certain localities small beds of scallops which have passed the age limit, are occasionally found, but usually the number in the bed is small. Several small beds and one large (Common Flats, Chatham, 1908) have come under the observation of the writer, who by no means claims that the two-year limit is a hard and fast rule, but rather that there are often exceptions, which, however, form but a small per cent. of the whole.

The age limit of the scallop ranges from twenty to thirty months. We find that the variation is due to several causes: (1) the spawning season, which makes possible a difference of two months in the age; (2) the environment, favorable or unfavorable, which lengthens or shortens the period of life; (3) seasonal differences, as during a mild winter the old scallops are under less strain than during a severe season; (4) the rate of growth and consequently the size of the scallop, as the small, slow-growing scallops apparently live longer than the large. This was noticeable with the set of 1907 at Monomoy Point, which grew very slowly, as compared with the sets of previous years, owing to the partial closure of the opening to the ocean and the consequent lessening of circulation in the Powder Hole during 1908. These scallops in the summer of 1909, when two years old, were scarcely larger than yearlings, and lived until the following September before they began to die, at least six months longer than the normal. In previous years in the Powder Hole a small per cent. of the scallops had lived until May and a still smaller number until August (twenty-five months), but this was the only set, as a whole, to pass to the twenty-sixth month, a fact probably explained by their small size and freedom from foreign growth.

The above statements are based on the following facts:—

(1) The writer has been able to find very few old scallops (twenty-seven months) during the fall dredging in waters of the Commonwealth. The scallop fishermen report in each locality the same result, with the exceptions above mentioned. This narrows the limit from general practical observation to twenty-seven months.

(2) The reports of fishermen upon the death of scallops in the last of the winter and in the spring, as well as the great destruction of beds at Dennis, Chatham, etc., prove that the scallop begins to die about the twentieth month of its life. This brings the period of death and decline between the twentieth and twenty-seventh month, or from March until October.

(3) The sets of 1905, 1906 and 1907 were followed from birth to death at the different scalloping sections by observations at stated intervals, and the results, except for the inroads of the scallopers, were conclusively proved by dredging on the scallop grounds.

(4) Detailed study of the sets of 1905, 1906 and 1907 in the Powder Hole, where the scallops were confined for life, shows conclusively that the average length of life is two years, even when undisturbed by dredging.

(5) Records from 500 scallops in pens at Monomoy for growth gave actual figures for death from old age.

The connection between the limited life of the scallop and the spawning season has been considered under the subject of "Spawning," in chapter III., and it is only necessary to again call the reader's attention

to the importance of the short life of the scallop in regulating the fishery by law. This knowledge is particularly applicable to protective legislation. The length of life permits but one spawning season, when the scallop is one year old. After spawning the average scallop is valueless for the maintenance of the race, and does not need protection. Thus the scallop under one year old, the "seed" scallop, is the only one that should be protected by law. No legislation is necessary for the scallop past its prime. For this reason restrictive legislation, such as limiting the catch by the town law, except when it is to the pecuniary advantage of the scalloper, to avoid "glutting" the market, is unnecessary, and only works to the detriment of the fisherman, as all scallops not taken will perish before another season. The fisherman should be given freedom in his dredging, provided he observes the all-important "seed" scallop law, as he can catch all the old scallops without injuring in the slightest degree the future industry.

The Growth Line.—The shell of the scallop is increased by calcified secretions of the mantle, which add fine concentric rings to the growing edge. If one observes the shell closely one will find that it is made up of microscopic growth lines, due to the method of growth.

On scallops which reach a second summer there is found a growth line, more or less pronounced, which can be likened to the year marks seen in cross-section of tree-trunks, and is given the name of the *annual growth line*. Growth lines with the oyster are helpful in determining the age, and this line marks the distinction between the adult and "seed" scallop, and has attained considerable prominence as the basis of the "seed" scallop law.

The *annual growth line* is formed in Massachusetts waters about May 1, when the scallops resume their growth after the cold winter months, during which all growth has ceased. Necessarily, during the long period of nongrowth, from November to May, the edge of the shell has become thickened or blunted by more or less wear, and when the new growth is secreted by the edge of the mantle on the inner side of the shell a distinct ridge is formed, marking the separation of the old and new growth. The location of the growth line varies between the limits of 10 to 65 millimeters from the hinge, depending upon the size of the scallop when it ceases growing in the fall. We have already shown that there is a similar variation in the size of the "seed" scallop, owing to difference in its situation and the time of spawning. As a rule, the line is 30 to 40 millimeters from the hinge. In some scallops it is very prominent, while in others it is difficult to discern at first glance; sometimes the shell shows a difference in color between the two parts, at other times both the old and new growth are alike, and it is necessary to run the finger down the shell to determine the ridge. However, these cases are the exceptions, and the average growth line is especially prominent on the lower or right side of the animal, the upper valve

usually being covered with numerous growths, both plant and animal, which may obscure the line.

As the formation of the annual line is due to cessation of growth during the winter, it logically follows that any check for a less or greater time will cause slight lines, which are entirely distinct from the annual growth line and are by no means as prominent, being merely heavier concentric layers. Growth lines of this sort can be produced on young scallops at any time by interfering temporarily with their growth. The same scallops repeatedly transferred from the spat boxes on the raft at Monomoy Point, and kept in an aquarium for even as short a period as one day, could be made to produce as many as three or four distinct growth lines. Large "seed" scallops and even adults, when transplanted from Harwich and Chatham to Monomoy Point, always showed the change by the formation of a line of growth.

The growth line is not caused by the spawning season, as has been supposed, since our investigations upon the effect of the spawning on growth indicate that there is no cessation during this period (June and July), and that before the beginning of the spawning there has formed during the month of May about $\frac{1}{8}$ of an inch of new shell. All our observations for the years from 1906 to 1909 have shown that the new growth begins about May 1, except for the variation of different years, and that the growth line is formed at a time previous to the spawning season.

Although the growth line appears when the scallop is but ten months old, it can for all practical purposes be considered as marking the first year of the scallop's life. While the spawning season is not completed until about the first part of August, these dates are included in the closed season, which lasts from April to October, and in a general sense the growth line can be associated with the spawning season, and in the open fishing season any scallop with the annual growth line is ready for capture. Risser (2) was the first to advocate the use of the growth line to distinguish the difference between the adult and "seed," while the Commonwealth of Massachusetts was the first to put into force a law based on the growth line as distinguishing the adult from the "seed" or immature scallop, which has not spawned. While we cannot say that every scallop with a growth line has spawned, we can definitely state that every scallop without a growth line has not spawned and is a "seed" scallop. The growth line has thus proved of great practical importance in scallop legislation, which is based on the facts obtained upon the length of life and spawning of the scallop in Massachusetts waters.

Growth during Spawning Season.—The spawning season has the wide limits from June 15 to August 15. The greater part of the spawning is accomplished during June and the first part of July. Corresponding to the spawning period there occurs a slowing in the rate of

growth (Fig. 85). Risser (2) has observed a similar occurrence with the growth of Rhode Island scallops, but declared that there is a complete check at this period, and to it attributes the origin of the annual growth line. This report has demonstrated that the growth line is formed at an early period, about May 1, by the resuming of shell formation after the nongrowth of the winter months, and has nothing to do with the spawning season. Likewise, no decided check in the growth of Massachusetts scallops is found during the spawning season, but rather the scallop continues to grow at about half its normal rate. The monthly rate of growth was determined for 1,900 scallops in four wire netting pens at Monomoy Point during 1906. It was found, by considering the entire summer's growth (May 1 to December 1) as 100 per cent., that the growth during May was 19.76 per cent., during June 8.33 per cent., during July 10.35 per cent., during August 20.39 per cent., showing that the rate of growth for the month preceding and succeeding the spawning season was over twice as fast as for the spawning months.

The reason for this slow growth can be attributed to the coincidence with the spawning season, and is best explained by assuming that the activities of the animal were directed for that period upon the propagation of its species, and less energy was used for the secretion of shell. Temperature, the great factor in determining growth, does not have any influence here, as the water during June and July was warmer than during May and colder than August. In fact, all natural conditions affecting the rate of growth were eliminated, leaving the spawning season as the direct cause in the lessening of the rate of growth.

Growth of the Young Scallop.—The young scallop at the age of forty-eight hours has increased in size by the formation of the embryonic shell. Previous to this time the ciliated larva was scarcely larger than the original egg. The period of first shell formation marks the beginning of real growth, which continues for the entire life of the scallop during the summer months. Since the growth during early life has been described in chapter III., it is only necessary to consider the growth after the scallop has become readily visible to the naked eye, *i.e.*, about $\frac{1}{25}$ of an inch in size.

The time of appearance of the set depends upon two factors, (1) locality; (2) year. During 1906 the visible appearance of "set" was recorded as follows: (1) Powder Hole, Chatham, August 7; (2) Stage Harbor, Chatham, July 24; (3) Edgartown, August 3; North Falmouth (Buzzard's Bay), July 20; Marion, July 20; showing a difference of fourteen days between two bodies of water not 10 miles apart, and an extreme variation of eighteen days. At Monomoy, between 1905 and 1909, the sets have appeared as early as July 24 and as late as August 7, showing the influence of seasonal change. (These dates do not indicate the first appearance, but when the average set was readily

discernible to the naked eye.) Stragglers can be found weeks before and after, due to the length of the spawning season.

The rate of growth of the young scallop is affected by the same natural conditions as the adult. Between the sizes of 1 and 15 millimeters, the average gain per day is 0.5 of a millimeter (about $\frac{1}{60}$ of an inch). As the scallop increases in size the actual growth becomes less.

The habit of attachment is of great importance to the scallop, not only occasionally saving it from destruction on foul bottom, but raising it in a position where the little animal can obtain a better food supply, thereby favoring its growth. Eel grass from its abundance proves the most common place of attachment, but is often detrimental to growth by shutting off the circulation of water. In comparing the growth of small scallops in eel grass and outside, the eel-grass scallops show a slower growth.

In summarizing the growth of the young scallop the following points are important: (1) the actual growth begins only with the first shell formation; (2) the time of set varies in regard to (a) locality, and (b) year; (3) the growth up to 15 millimeters averages $\frac{1}{60}$ of an inch per day; (4) growth becomes less and less as scallop increases in size beyond the 15 millimeter mark; (5) power of attachment aids growth; (6) conditions governing growth are the same as for adult; (7) growth of the young is faster than for yearling scallops, both in (a) actual gain, and (b) in volume.

Growth of the Average Massachusetts Scallop. — Owing to the variation in the growth of the scallop in the different localities, it is difficult to strike more than an approximate average for the size of the yearly sets and the typical Massachusetts scallop. Two classes of scallops are found, (1) the shallow-water or eel-grass scallop, and (2) the deep-water or channel variety. The following tables are compiled from the average growth in the different localities for a period of three years. The height of the scallops is given in millimeters, 25.4 millimeters being equivalent to 1 inch.

The Average Scallop.

Snr.	AVERAGE SIZE (MILLIMETERS).		Per Cent. Gain in Volume.
	May 1 (Ten Months).	December 1 (Seventeen Months).	
1904,	33.40	60.99	632.75
1905,	37.50	62.30	525.78
1906,	31.82	60.51	678.04
Average,	34.24	61.27	612.19

Size of Scallop (Millimeters).

DATE.	1904.	1905.	1906.	Average.
Aug. 1,	2.00	2.00	2.00	2.00
Sept. 1,	12.40	13.76	11.82	12.66
Oct. 1,	22.64	25.34	21.61	23.20
Nov. 1,	32.30	36.26	30.78	33.11
Dec. 1,	38.40	37.50	31.82	34.24
May 1,	33.40	37.50	31.82	34.24
June 1,	38.85	42.20	37.49	39.51
July 1,	41.15	44.27	39.88	41.77
Aug. 1,	44.01	46.84	42.85	44.57
Sept. 1,	49.64	51.90	48.70	50.08
Oct. 1,	55.18	56.88	54.46	55.61
Nov. 1,	60.40	61.76	59.89	60.68
Dec. 1,	60.99	62.30	60.51	61.27

Growth in Various Localities.— The growth of the scallop is largely determined by its environment. Owing to the diversity of natural conditions within small bodies of water more definite conclusions can be drawn from special localities than by comparing one locality or section with another, owing to the difficulty of determining the average growth for so large an area. Nevertheless, it is of interest to compare the growths in the different parts of the State in a general way, without making too fine a distinction between the individual towns. The following figures are based on a large number of measurements of several sets:—

Size of Scallops (Millimeters).

DATE.	THE ISLANDS.		THE CAPS.		BUZZARD'S BAY.	
	Nantucket.	Edgartown.	Chatham.	Monomoy.	North Falmouth.	Marion.
Aug. 1,	2.00	2.00	2.00	2.00	2.00	2.00
Sept. 1,	10.85	10.10	12.43	12.61	13.77	16.29
Oct. 1,	19.57	18.09	22.71	23.05	25.36	30.36
Nov. 1,	27.79	25.62	32.40	32.30	36.30	43.64
Dec. 1,	28.72	26.48	33.50	34.02	37.54	46.15
May 1,	28.72	26.48	33.50	34.02	37.54	46.15
June 1,	34.53	32.34	38.72	39.33	42.59	49.94
July 1,	36.98	34.81	40.92	41.57	44.72	51.96
Aug. 1,	40.02	37.85	43.65	44.35	47.37	54.47
Sept. 1,	46.02	43.83	49.03	49.58	52.59	59.42
Oct. 1,	51.96	49.88	54.33	54.23	57.77	64.29
Nov. 1,	57.50	55.49	59.33	60.32	62.58	68.88
Dec. 1,	58.13	56.13	59.90	60.90	63.13	69.40

Comparison of the Different Sets.— In the second table given under the average Massachusetts scallop a comparison of the different sets can be found for the whole scalloping district. A better idea of the variation can be given in comparing the sets for four years in the same locality, the Powder Hole:—

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Srr.	Number.	SIZE (MILLIMETERS).	
		May 1.	December 1.
1904,	200	34.55	61.59
1905,	300	34.00	62.90
1906,	300	28.09	59.35
1907,	500	21.50	42.50

The 1907 set was peculiar in showing a much slower growth than the previous sets. This was due to the partial closure of the entrance to the Powder Hole during the summers of 1907 and 1908, which deprived the scallops of the circulation of water which they formerly had. This peculiar set has already been discussed in connection with the length of life of the scallop, as nearly all reached the age of twenty-seven months.

Comparison with Rhode Island. — A comparison of the rate of growth of the different sections in Massachusetts with the Narragansett Bay scallops shows that the average Massachusetts scallop is much smaller and less rapid in growth than its neighbor, except in the Buzzard's Bay section, where the conditions more nearly approximate Narragansett Bay. This difference is probably due to the warmer water, which permits earlier spawning and more rapid growth. The Rhode Island figures in the following table are taken from the report of Jonathan Risser (2) in the Rhode Island Commission of Inland Fisheries, 1904: —

Size of Scallops (Millimeters).

DATE.	Rhode Island.	Buzzard's Bay.	Cape Cod.	Islands.	Average Massachusetts.
Oct. 2, . . .	42.00	27.86	22.88	18.98	23.20
Dec. 4, . . .	44.50	41.35	33.76	27.60	34.24
Jan. 11, . . .	55.00	41.35	33.76	27.60	34.24
March 20, . . .	56.80	41.35	33.76	27.60	34.24
April 21, . . .	58.80	41.35	33.76	27.60	34.24
May 30, . . .	60.00	46.27	39.03	33.44	39.51
July 1, . . .	60.00	48.34	41.25	35.90	41.77
Aug. 1, . . .	62.75	50.92	44.00	38.95	44.57
Sept. 18, . . .	71.60	59.02	52.31	48.94	58.42
Oct. 16, . . .	79.00	63.38	57.06	53.89	58.11
Nov. 16, . . .	81.00	66.00	60.10	56.83	60.98
Dec. 3, . . .	86.00	66.27	60.40	57.13	61.27
Jan. 11, . . .	85.00	66.27	60.40	57.13	61.27

Age and Growth.— With the exception of the winter months (December to May), during which no growth takes place, the scallop continues to increase in size until its death. The proportionate growth as determined by the volumetric increase steadily diminishes after the period of first shell formation (the veliger or embryonic shell). On the other hand, the actual gain in inches or millimeters is approximately constant for the first summer, then slowly decreases during the second and even third, provided the animal lives beyond the two-year limit. The point is well illustrated by the following experiment: scallops of the 1904, 1905 and 1906 sets were suspended in wire cages under similar conditions from a raft at Monomoy Point for a period of fifty-three days during the summer of 1906 (Fig. 86). The smaller (younger) scallops showed a greater capacity for growth both in actual increase and in volume. The 1904 set gave an actual increase of 2.10 millimeters in height, or 112 per cent. in volume, a return of less than $1\frac{1}{8}$ bushels for every bushel planted; the 1905 set 3.94 millimeters in height, or 125 per cent. in volume, a return of $1\frac{1}{4}$ bushels; the 1906 set 10.86 millimeters in height, or 309 per cent. in volume, a return of over 3 bushels. From these figures it is evident that the "seed" (1906 set) gave about twelve times the growth in volume of the yearlings (1905 set), and twenty-five times the growth of the 1904 scallops, which had lived beyond their allotted life; and that there is a successive decrease, both numerically and volumetrically, in the rate of growth with the aging of the scallop.

Environment and Growth.— Two great factors influence all animal and plant life,— heredity and environment. In the case of the scallop, environment seems to possess the greater influence on the variation of the species, as varieties are more dependent upon the natural surroundings than upon hereditary characteristics. By environment is meant the natural conditions within which the animal lives, and which determine its struggle for existence. The question of food, enemies, exposure, protection, situation in large or small bodies of water, in or out of tidal currents, temperature, etc., are all factors influencing to a more or less extent the life and habits of the scallop, making it large or small, heavy or light shelled, firm or poor meated, etc. Particularly with marine animals does environment largely determine size, shape, habits and rate of growth.

With many aquatic animals larger specimens of the same species are found in the great bodies of water than in the small, showing that the area of water, either by a more plentiful food supply or in other ways, determines the general size. Looking at the matter from a different standpoint, that of current, it seems that scallops which have the greater amount of water passing over them (which can be compared to residence in a larger area) are larger and of faster growth than the scallops which do not have the same volume of water.

(a) *Growth in Respect to Current.*—The most important factor in shellfish growth is a good current of water. The use of the word current does not mean necessarily a rapid stream or an exceedingly swift flow, but a good circulation of water over the bed.

The chief office of the current is as a *food carrier*. The scallop obtains its nourishment from microscopic plants, called *diatoms*, which are found throughout the water. The amount of this food is approximately uniform, and the scallops situated in a current naturally receive more food than those in still water. With mollusks the growth is directly proportionate to the amount of food, and the scallop receiving the most food increases in size most rapidly. A homely comparison can be made by likening the scallop in the current to the man seated at a moving lunch counter, who is able to continually obtain a new supply of food, while his neighbor at the stationary table (the scallop in the still water) is limited to the food within reach. For all practical purposes current means food, and within limits the increase in current indicates the increase in the amount of food, thus furnishing an index for the rate of growth. Theoretically, other factors enter into the problem, such as (1) variations in the amount of food in different localities; (2) the feeding capacity of the scallop, since beyond a certain maximum value an increase in current means no increase in the amount of assimilated food; (3) the freedom of the water from contamination and silt, which impedes the feeding powers of the animal. The shellfish culturist can take the current as his guide for planting, and follow the rule that, as long as the flow of water does not harm the planted shellfish in other ways, the swifter current gives the faster growth.

Current not only brings food to the scallop but also furnishes the lime in solution which is utilized in building the shell, a process as essential in the growth of the scallop as the nourishment of the soft parts by the food in the water. The amount of lime in solution varies in different waters, but this difference is largely obviated by the changes in the current. As an example, a scallop will grow no faster in water rich in lime which is comparatively stagnant than it will in water relatively much poorer where there is a stronger current.

The third office of the current is a purely sanitary one. It sweeps away the decaying vegetable matter so destructive to scallops situated in thick eel grass, and all other poisonous débris which would otherwise kill the scallops by contamination, or at all events would check their growth.

The relationship of current to growth has been experimentally shown in several ways, all of which demonstrate that in the case of the scallop current is the main essential for rapid development. The following observations and experiments are cited as confirmatory evidence:—

(1) *Eel-grass v. Channel Scallops.*—In observing the catch from the scallop beds, it was recorded that the larger scallops always came

from the deep water or channel, while the smaller were taken in the eel grass or shallow water. This difference held true to such an extent that the scallop fishermen could tell by the appearance of the scallop from what section of the bed it came. The shallow-water scallops are much smaller, usually proportionately thicker, and have not the large "eye" and fine appearance of the channel scallops, which are preferred by the scallopers. From a study of the natural conditions of the scallop beds, it appeared that this difference in growth was not due to the mere change in the depth of water but was due to current. The channel scallops on clear bottom receive better circulation of water than in the eel grass, which cuts off nearly all flow of water. Places were found where scallops in deep water without current showed no more growth than the shallow-water variety, while, on the other hand, shallow-water scallops situated near the mouth of an estuary where the tide flowed swiftly back and forth were nearly as large as the deep-water variety. Therefore, while the general distinction between large and small scallops appears to be merely that of deep and shallow water, the fundamental reason is the presence or the lack of current.

(2) *Penned Scallops at Monomoy Point.*—Two pens were located in the Powder Hole at Monomoy Point in 1906. The first was located in an unfavorable situation in shallow water, in thick eel grass which shut off all circulation. The second pen was located in a more favorable situation, where the eel grass was thin and a gentle circulation was caused twice a day by the inflowing of the tide. This pen was situated close to the shore and was by no means adapted for more than ordinary growth. In comparing the growth of the two pens from May 1 to August 1 for the same sized scallops it was found that pen 1 gave a gain in volume of 12 per cent., while pen 2 furnished an increase of 35 per cent. for the same sized scallops, or nearly three times as fast as pen 1. This furnishes a concrete example of the effect of the lack of circulation, as other conditions were very similar in the two pens, which were situated only a short distance apart, in the same depth of water, and about the same distance from shore.

(3) *Basket Growth on Raft and on Shore.*—Scallops of the 1906 set were obtained from Stage Harbor, Chatham, Sept. 7, 1906, and suspended in wire baskets from the raft (Fig. 79), and in pen 2 near the shore. The scallops on the raft, which was located in the deepest part of the Powder Hole, received the best circulation of water and showed a surprisingly fast growth. The difference is brought out by comparing the raft growth with the natural growth of the Stage Harbor set for the same time, and for the basket growth in pen 2 of the same set of scallops. The gain from September 7 to November 22, a period of seventy-six days, was 17.28 millimeters for the raft, 14.08 millimeters for the Stage Harbor scallops, and 10.40 millimeters for the shore. Considering the raft growth as 100 per cent., Stage Harbor would be

81.48 per cent., and the shore 60.18 per cent. The actual gain in volume for each locality would be raft 662 per cent., Stage Harbor 475 per cent., shore 293 per cent. (Fig. 88).

(4) In comparing the growth of penned scallops during 1906 at Chatham, Powder Hole, Monument Beach and Marion in reference to the natural conditions, the pens with the best circulation of water invariably showed the fastest growth, as can be observed in detail by referring to the table under artificial growth.

(5) *The Stage Harbor Set.* — An excellent opportunity for observing the effect of current on the growth of young scallops was found at Stage Harbor in 1906. The set was located at the entrance to Stage Harbor on a flat extending about 90 yards from the east shore to the channel, which curves close to Harding's Beach, on the opposite side. Thick eel grass covered this flat except near the channel, where it grew scatteringly. The water at mean low tide is from 6 to 9 inches deep over most of the flat, gradually deepening at the edge of the eel grass toward the channel. The rise and fall of the tide is about $2\frac{1}{2}$ feet. At low course tides the greater part of the flat is exposed. The difference in the flat is mostly due to the tide, which sweeps in and out of the harbor at every rise and fall, so that there is a strong current always running in the channel. The result is to give that portion of the flat near the channel more current than the portion further away, and the part near shore hardly any. The young scallops were evenly distributed over the flat, although the channel portion was not so heavily set. The growth of scallops of the 1906 set was followed by dividing the flat into three sections, passing from the shore to the channel, each roughly 30 yards wide, and by measuring the average size of scallops in each of these sections at different dates. Four measurements were made, Oct. 26, 1906, April 4, 1907, May 1, 1907, and July 1, 1907. By calculating the difference in the rate of growth and size at each date, the following figures were obtained. Giving the area near the channel (the area of fastest growth) 100 per cent., the middle portion would have a value of 87.04 per cent., while the shore section would have 77.79 per cent. These figures conclusively show the effect of location on the growth of scallops, as in this case scallops of the same set manifested a much greater growth when situated near circulating water. Placing the same in measurements as taken July 1, 1907, when the scallops were exactly one year old, we would have in current portion scallops 42.81 millimeters in size, middle, 37.77 millimeters, shore, 32.95 millimeters, showing a difference of nearly 10 millimeters between the current scallops and the shore, possibly 70 yards apart and of the same set. Computing the growth of the standard scallop (25 millimeters) for each of these areas for a definite period, the following comparative gains in volume, 482 per cent., 280 per cent., and 146 per cent. were obtained (Fig. 87).

(b) *Growth and Soil.* — It is impossible to state definitely the exact effect of soil upon the growth of the scallop. The character of the bottom apparently affects the growth but little, as the scallop rests only on the surface and is constantly shifting its position. In this way the scallop is different from the quahaug and clam, which lie buried under the surface. While the adult scallop is little affected by the nature of the soil, the young scallop would soon perish in soft mud were it not attached to eel grass during the early period of its life. The best bottom seems to be a tenacious sand (sand with a slight mixture of mud) with thin eel grass. The most common type, that of the shallow flats, is of a sandy nature with various thicknesses of eel grass. In the case of the large channel scallop, the soil is either sand, gravel, hard mud, shells, with but little eel grass.

The only means of influencing the growth is by the action of the organic acids in certain soils which affect the chemical composition of the lower valve, the only part of the scallop in contact with the soil. Sometimes in cold weather the scallop sinks down in little hollows in the soil, bringing more surface in contact with the bottom. Fortunately, localities of injurious nature are of infrequent occurrence on the scallop grounds and are limited in extent.

(c) *Growth in Eel Grass.* — The soil indirectly affects the growth of the scallop by the production of eel grass, which is found in more or less abundance on the scallop beds. Eel grass, especially on the shallow flats, occurs either as (1) thick clusters with open spaces intervening, (2) thinly scattered or (3) thick masses. Only in the last case is eel grass a serious check to growth, as it then cuts off a proper circulation of water, which is the main essential for rapid development, although in the other two types there is more or less interference, according to the thickness of the eel grass. By a comparison between growth on clear sand bottom and in thick eel grass, where other conditions were approximately the same, the scallops on the clear bottom show a greater rapidity of growth than those within the grass, showing that the difference was mainly due to a lack of circulation.

(d) *Effect of Temperature.* — The factor next in importance to current in determining the growth of the scallop is temperature. The scallop needs a temperature over 45° F. for growth, thus differentiating the growing months (May 1 to December 1) from the winter months (Fig. 89). Naturally, cessation of growth would be attributed to a lack of food. While by actual count there is a decrease in the amount of food (diatoms) in the water about December 1, it is not sufficient to account for the cessation of growth at this date. Indications point to the fact that the activity of the scallop in procuring food has declined, as the animal has become sluggish with a lowering of the water temperature, and during the winter months remains inert on the bottom, nestling in little hollows in the sandy soil.

Waters of high temperature usually show more rapid growth, probably due to (1) the earlier start in the spring and longer season, (2) more rapid growth throughout the summer months from an increased food supply. Diatoms multiply more rapidly in warm waters and the food supply is consequently greater. The effect of temperature can be seen by comparing the scallops of Cape Cod and Buzzard's Bay. The former do not attain the size of the latter, which are the largest scallops produced in the Commonwealth. The same comparison holds true between Rhode Island and Massachusetts, as in the warmer waters of Narragansett Bay the scallops develop more rapidly. While in both cases other natural conditions play an important part, it is only fair to assume that temperature is a most important factor.

(e) *Growth and Salinity.* — The oyster is extremely sensitive to changes in the salinity of the water, both in regard to spawning and growth. The growth of the scallop, on the other hand, is not materially affected by these changes. A sudden decrease in salinity, as after a severe rain, often kills young scallop larvæ, and transferring scallops from water of one density to another during the breeding season has been found to check the spawning.

Scallops are found in waters ranging in density from 1.010 to 1.027, i.e., an equal mixture of salt and fresh, as in mouths of rivers, to extreme salinity. Rough experiments have demonstrated that scallops live and grow equally well between these limits, and that any differences in growth are due to other conditions.

(f) *Depth of Water.* — The question of the most favorable depth for growth is of importance to the scallop planter. In nature scallops are found at any depth, from flats exposed at low tide to 60 feet, although the usual limits are less than 25 feet. In too shallow water severe winters destroy the sets, so the scallop should be deep enough to escape the ice. As shown by the channel v. eel-grass (shallow water) scallop, the greater growth occurs in the deep waters; but, as has been stated, this is essentially due to the better circulation in the channel.

Scallops were suspended in wire baskets from the raft in the Powder Hole at different depths during the summer of 1906. The water was 20 feet deep. Four baskets, each containing 100 "seed" scallops about 20 millimeters in size, were suspended for seventy-six days at 6, 7, 8 and 9½ feet from surface. When measured a regular decrease of about one millimeter per foot was found, the 6-foot basket evidencing the greatest gain, and the rest less in definite order, ending with 9½-foot basket. These figures indicate that the best depth for this particular locality was about 5 feet from the surface. Similar experiments with older scallops gave negative results.

Artificial Growth. — The greater part of the growth experiments on the scallop were conducted under the artificial conditions that would be employed in scallop culture. In order to record the rate of growth

correctly, it was necessary to have some means of confining the scallops. This was done in three ways: (1) pens of wire netting; (2) wire cages; (3) an inclosed body of water, the Powder Hole. Only the first two can properly be considered artificial, as in the Powder Hole the scallops were in their natural environment. The records were taken at monthly intervals, three measurements being taken of each scallop.

The pens were located at Monomoy Point, Chatham, Nantucket, Monument Beach, Marion, and in the Annisquam and the Essex rivers. The size of the pens ranged from 40 to 400 square feet, either of sufficient height to extend above the average tide, or covered with a netting to prevent the scallops escaping. The posts were made of 2 by 3 feet joists firmly fixed in the soil and placed at sufficient intervals to hold the netting taut. Wire netting (1¼-inch mesh) and old seines were used, the greatest difficulty being to secure the bottom firmly, which was done by base-boards and by fastening the netting in the sand with long wooden pegs. (A complete description of the construction of the pens is given in chapter VII.) It is only fair to state here that pens can probably be improved in such a manner that better results can be obtained, and many of the difficulties of artificial culture can be eliminated.

(a) *Artificial compared with Natural Growth.*—For some reason the scallops in the pens do not grow as rapidly as the unconfined scallops in the same locality. This is proved by a comparison of the growth of penned and unpenned scallops in the Powder Hole in 1905, and also by the table of comparative growths in the pens in the various localities during the summer of 1906. In the first case the growth approximated 14.30 millimeters for the penned, as compared with 25.04 millimeters for the unpenned, showing a gain of 10.74 millimeters, or 75 per cent. The average growth from five pens was 16.77 millimeters, as compared with 26.29 for the unpenned, showing a difference of 9.52 millimeters, or 56.8 per cent. It seems peculiar that merely limiting the range of the scallop should have this detrimental effect upon its growth. Several explanations are in order: (1) lack of food by overcrowding in the pens; while this is a very probable explanation, as the scallops were much thicker in the pens than without, it does not seem to hold true for the pens which contained but few scallops, as these no wise differed from the others; (2) the accumulation of seaweed and other plant life on the meshes of the netting, which prevented the proper degree of circulation; (3) the lessened activity of the scallop as compared with the freedom of those without, *i.e.*, lack of exercise. Probably to no one of these explanations can be attributed the whole cause, but rather that all three are more or less involved.

This fact, when applied to scallop culture, is important, as the planter would naturally be desirous of at least attaining as good a growth, if not better, than under natural conditions, and yet if he confines the scallops in small pens he is unable to obtain a maximum yield. There

is no reason to believe that this difficulty cannot be overcome by the construction of improved pens, and by requisite care in cleaning. On the other hand, as is stated in chapter VI., under "Artificial Culture," scallop culture can only be successfully conducted in inclosed bodies of water, since the expense of erecting pens would offset the profits. Pens should merely be used to hold the immediate catch for market and rarely utilized for rearing purposes.

Penned and Unpenned Scallop Growth in 1906.

LOCATION.	PENNED.		UNPENNED.	
	Gain (Millimeters).	Gain in Volume (Per Cent.).	Gain (Millimeters).	Gain in Volume (Per Cent.).
Powder Hole,	15.84	406.00	28.90	965.00
Chatham,	24.25	726.00	26.40	831.00
Monument Beach, . .	16.00	411.00	25.59	790.00
Marion,	11.00	280.00	24.25	729.00
Average,	16.77	456.00	26.29	828.00

(b) *Results from Artificial Growth.* — The greater part of the points enumerated in this chapter were obtained from the experiments upon confined scallops, which, although merely approximating natural conditions, were the only means available for arriving at definite conclusions upon the growth of the scallop. For comparative work and as supplemented by definite observations on the natural beds, they proved of great value in respect to the following: (1) length of life; it was necessary to confine the scallops to ascertain the duration of life, which results were supplemented by use of tagged and unconfined scallops; (2) the growing months and the relative economic value of each month, mainly determined from the pen experiments at Monomoy; (3) the comparative rate of growth of the different sizes, determined from pen and cage experiments; (4) growth during the spawning season; (5) the effect of environment and natural conditions which affect the rate of growth, resulting from (a) currents, (b) soil, (c) eel grass, (d) temperature; (6) density; (7) depth of water. These were determined by a comparison of the natural conditions for each pen and the effect which each had upon growth.

Among others, the following facts have been demonstrated by artificial growth experiments: —

(1) *Scallops transplanted to Waters North of Boston.* — Three pens were planted in May, 1906, two of these in the Essex River and one in the Annisquam River, with scallops brought from Cape Cod. Unfortunately, no records could be obtained as the pens were swept away by the swift tidal currents of the north shore rivers, and no trace of the

scallops were obtained. Undoubtedly there are but few places in these rivers where the temperature and other conditions are such that transplanted scallops can live. As a whole, the region is unsuited for the scallop and no industry can ever be expected.

(2) *Deformity of Shell of Scallops grown under Artificial Conditions.*—Scallops confined under artificial conditions frequently show deformities. In nature, deformities in shell occur occasionally, usually being due to the loss of part of the secreting mantle or by contact with some object. The young "seed" scallops confined in the wire cages furnished three types of deformity: (1) a general type, the ratio of width to height being much greater than in the normal "seed;" (2) the thickness of the caged "seed" exceeded the thickness of the normal scallop; (3) many individuals in the cages showed indented shells, angular projections corresponding to the position in which they had rested in contact with the wire sides, and numerous other malformations occasioned by their cramped quarters. All these factors operated against perfect work in recording the growth of the caged scallop.

(3) *Growth of Small and Large Scallops of the Same Age.*—The size of the "seed" scallops of any set vary greatly, but by the time they are ready for market the size is more nearly uniform for scallops under similar conditions, *i.e.*, there is less individual variation. One of the surprising facts noted was that the penned scallops, by the increased rapidity of growth, caught up with the larger before the season was over. In one pen two lots of scallops which on May 1 measured 38 and 46 millimeters respectively, by December 1 were each 60 millimeters in height, the smaller scallops having made up the difference of $\frac{1}{8}$ of an inch, and had a gain in volume of 477 per cent., while the 46-millimeter scallop had only increased 249 per cent. in volume (Fig. 90). In several cases this fact was observed and substantiated, likewise from measurements of the natural scallops, showing that the scallops which are backward in growth the first year, either from poor location or late spawning, when placed under favorable conditions have a greater potential energy for growth than the larger "seed," and practically make up the loss in the first season by increased gain during the second.

(4) *Individual Variation and Heredity.*—Each scallop has its individual characteristics. Take any number of scallops of the same size, no matter how few, and let them grow for a month or more. When measured considerable variation will be found, in spite of the fact that all the scallops had the same advantages and were under the same conditions. It is due to the individual variation in the growing powers of the different scallops, such as, *e.g.*, their capacity for feeding or shell secretion, and is primarily the result of either injury or heredity. Individual scallops have been marked and it has been found that generally a slow-growing scallop will keep the same rate during the entire season, in spite of changed position.

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(5) *Overcrowding.*—Overcrowding tends to decrease the general rate of growth, as too many mouths are drawing from a limited food supply, and unless there is considerable circulation of water the amount per capita is limited. The stronger the current the greater number can be planted per square foot. The wire cages suspended from the raft demonstrated the effects of overcrowding. Under uniform conditions "seed" scallops averaging 21 per cubic foot gained 21.45 millimeters in height, or 1,092 per cent. in volume, in seventy-six days, while those averaging 153 per cubic foot gained 15.59 millimeters, or 659 per cent. in volume, a difference of 433 per cent. In this case the circulation of water was excellent, yet the difference was decidedly marked.

(6) *Cage v. Natural Growth for Small Scallops ("Seed").*—The 1906 set on the raft was recorded by confining some in wire cages of small mesh, increased in size as the scallops became larger, and by measurements of the scallops which naturally were attached to the different spat boxes. The result was that the caged scallops gained only 15.70 millimeters between August 17 and November 22 (ninety-seven days), both classes being 3 millimeters in size on August 17, while the natural set gained 29 millimeters in the same period. The difference is explained by (1) lack of food, the meshes of the cage shutting off the circulation of food organisms; (2) abnormal growth, due to deformities resulting from cage environment. It is impossible to overcome these difficulties in obtaining the rate of growth of the scallop from caged specimens.

1905 Set during 1906.

	POWDER HOLE.		CHATHAM.	MONUMENT BEACH.	MARION.
	Pen 1.	Pen 2.	Pen 3.	Pen 4.	Pen 5.
May 1, 1906, . .	51.00 mm.	45.30 mm.	42.48 mm.	47.50 mm.	50.46 mm.
June 1, 1906, . .	51.85 mm.	48.43 mm.	47.27 mm.	50.18 mm.	52.63 mm.
July 1, 1906, . .	52.27 mm.	49.75 mm.	49.29 mm.	51.60 mm.	53.55 mm.
Aug. 1, 1906, . .	52.80 mm.	51.39 mm.	51.80 mm.	53.40 mm.	54.69 mm.
Sept. 1, 1906, . .	53.83 mm.	54.62 mm.	56.74 mm.	56.80 mm.	56.93 mm.
Oct. 1, 1906, . .	54.85 mm.	57.80 mm.	61.61 mm.	60.19 mm.	59.14 mm.
Nov. 1, 1906, . .	55.81 mm.	60.80 mm.	66.20 mm.	63.15 mm.	61.22 mm.
Dec. 1, 1906, . .	55.92 mm.	61.14 mm.	66.73 mm.	63.50 mm.	61.46 mm.
Gain,	4.92 mm.	15.84 mm.	24.25 mm.	16.00 mm.	11.00 mm.
Gain in volume for standard 30 millimeter scallop, .	150%	406%	726%	411%	280%

Natural Conditions.

	MONOMOY.		CHATHAM.	MONUMENT BEACH.	MARION.
	Pen 1.	Pen 2.	Pen 3.	Pen 4.	Pen 5.
Size of pen, .	15 x 10 feet, .	40 x 10 feet, .	7 x 6 feet, .	10 x 10 feet, .	10 x 10 feet.
Location, . .	Bay, . . .	Bay, . . .	Entrance to harbor.	Bay, . . .	Small cove.
Distance from shore.	30 feet, .	20 feet, .	270 feet, .	20 feet, .	150 feet.
Current, . . .	None, . . .	Fair, . . .	Excellent, .	Fair, . . .	Slight.
Soil,	Coarse sand,	Coarse sand,	Hard yellow sand.	Gravel sand,	Soft mud.
Eel grass, . .	Thick, . . .	Thin, . . .	Very thin, .	None, . . .	Thick.
Rise of tide, .	2½ feet, .	2½ feet, .	3.3 feet, .	4 feet, . . .	4 feet.
Depth of water,	1½ feet, .	2½ feet, .	1 foot, . . .	2½ feet, .	1½ feet.
Salinity, . . .	1.021, . . .	1.021, . . .	1.020, . . .	1.019, . . .	1.017.
Number of scallops.	610, . . .	2300, . . .	100, . . .	325, . . .	338.
Enemies, . . .	Oyster drill,	Oyster drill,	Starfish, . .	Oyster drill,	Oyster drill.

CHAPTER VI.—THE INDUSTRY.

While a description of the natural conditions of the beds, the methods of capture and the preparation of the scallop for market may prove of slight information to the fisherman, the general public has little knowledge of the methods used in the fishery. For this reason the following pages are primarily intended for the average reader, although different methods are employed in the various parts of the coast, and often the scallop fishermen in one locality are only familiar with the methods used in their immediate vicinity. In such cases information as to methods in other localities as regards implements, boats, dredges, etc., is an important factor in the development of the industry, and since the aim of this report is the improvement of the scallop fishery, no apology is necessary for the repetition of special parts of the Mollusk Report of 1909.

The Fishing Grounds.

Scalloping territory is a variable asset, as the beds are constantly changing according to the location of the yearly sets, and a description of the grounds for any reason may vary from preceding or succeeding periods. In a general way the location and distribution of the scallop beds are shown on the accompanying map (Fig. 78). For greater detail the reader is referred to the Mollusk Report of 1909.

The scalloping territory, which is entirely confined to southeastern Massachusetts, can be separated into four main divisions: (1) the north side of Cape Cod; (2) the south side of Cape Cod; (3) Buzzard's Bay; (4) the islands of Martha's Vineyard and Nantucket.

North Side of Cape Cod. — While there is some evidence from old records that scallops once existed as far north as Boston, they are not found at the present time further north than Plymouth, where it is reported that within the past few years a few could occasionally be gathered on the eel-grass flats of the harbor. Between Plymouth and Provincetown scallops can be obtained at Barnstable, Brewster, Wellfleet and Provincetown, but no extensive industry is carried on. This section, owing to certain unfavorable conditions, probably never will be suitable for a prosperous fishery such as is maintained on the south side of the Cape.

Natural conditions are practically the same for the entire section. Plymouth, Barnstable, Wellfleet and Provincetown harbors are in many respects similar, except that the two latter have different soil. The chief characteristic is the great rise and fall of the tide, averaging about 10 feet, which leaves exposed at low water vast areas of flats on which the scallops perish during the winter. Another unfavorable factor is the extreme swiftness of the tides, for example, in Barnstable and Plymouth harbors, which cause a continual shifting of the sand bars and wash the scallops upon the flats, where they are at the mercy of the elements. Every form of sea life has its range, and Cape Cod may be considered as the northern barrier in the distribution of the scallop.

The primitive methods of gathering the scallops by hand from the exposed flats, or by pushers and dip nets in the shallow water, is followed. No regular dredging is carried on, and the industry, except during the last two years at Brewster, has not been considered of any importance. The origin of the scallops which wash ashore on the flats of Cape Cod Bay at Provincetown and Brewster is unknown. The fishermen believe that in the deeper waters of the bay is a large bed, which furnishes the scallops that are annually washed ashore. In spite of the fact that this bed has never been located, there is every reason to believe in its existence.

(a) *Barnstable Harbor.* — On the eel-grass flats on the south side of the harbor a few scallops can be found at the present time; but there is not a sufficient number to make a regular business, such as was carried on in 1877-78, according to Clark (11). The chances are that a severe winter or some other adverse condition killed all the scallops in this locality, and thus, by destroying the spawners, rendered impossible any future supply.

(b) *Orleans and Brewster Flats.* — Along the bay shore of these towns, about $\frac{1}{2}$ mile from the high-water line, scallops are found every winter in more or less abundance, varying from a scant few to a sufficient quantity, as in 1908-09, to make a profitable business for the town of Brewster. The scallops, unless gathered, soon perish, as they lie on the flats fully exposed to the chill of winter.

(c) *Wellfleet Harbor*. — Scattering scallops are found near Billingsgate Island, on the north side of the harbor, and east of Jeremy's Point, but no regular fishing is carried on.

(d) *Provincetown Harbor*. — On the shore of the east bend of the harbor, toward Truro, scallops are washed ashore in varying amounts by the southwest winds. About fifteen years ago scallops were reported as numerous, and it was not uncommon for a man to pick up 5 bushels at one tide, but since 1900 few scallops have been found.

South Side of Cape Cod. — This section comprises the towns on the south shore of the Cape from Chatham to Mashpee. Here conditions are extremely favorable, except for an occasional southerly blow, which at times is sufficiently strong to wash the scallops in windrows on the shore. Only the shellfish in the exposed waters on the open coast are subject to this loss. The other conditions, such as a small rise and fall of tide (about 2 feet), good circulation of water, suitable bottom and depth of water, are all favorable to the habitation of scallops. On some flats during the low-running winter tides there is considerable exposure, as on the common flats of Chatham, and many scallops perish annually. The greater part of the fishery is conducted on the open coast, at some distance from shore, by dredging, or with "pushers" on the low flats which skirt the shore. Scallops are also plentiful in the inclosed bays which line the shore, such as Stage Harbor, Chatham; Lewis Bay, Hyannis; and Oysterville Bay, Barnstable. The average size of the scallop in this section is 2.13 inches. Few natural enemies are found. Starfish and oyster drills are present, but not in sufficient number to be of material damage. The total area comprised in this section is 12,700 acres.

(a) *Chatham*. — Scallops are found only in the southern waters of the town. Between Inward Point and Harding's Beach many acres of eel-grass flats, sheltered from the open ocean by Monomoy Island, furnish excellent grounds for scallops. The entire area of these grounds is approximately 2,000 acres, although this whole territory is never completely stocked in any one year. During the season of 1907-08 the following places constituted the scalloping grounds: —

(1) Island flats in Stage Harbor, on the east side of the channel, opposite Harding's Beach, furnish a number of scallops, which are caught the first of the season, as these flats were near the town. Here the water is not more than 1½ to 2 feet deep at low tide, and thick eel grass covers the greater part except near the channel.

(2) Directly south of Harding's Beach lies John Perry's flat, commonly known as "Jerry's," where there has been good scalloping for many years.

(3) The western half of the Common Flats furnished the best scalloping in 1907-08, as the scallops, though small (6 pecks to a gallon),



were plentiful. These flats run nearly dry on low course tides, and are covered with eel grass. Nearly every year there is a heavy set of scallop seed, which, because of the exposed nature of the flats, is wholly or partially destroyed. The entire set was destroyed in the winter of 1904-05, while 30 per cent. was lost in 1906-07.

(4) On the flats just south of Inward Point was another bed of scallops.

(5) In the bend north of Inward Point scallops were plentiful.

(6) On the northwest edge of the Common Flats scallops can be dredged over an area of 160 acres at a depth of 5 fathoms. These are of good size, opening $3\frac{1}{2}$ quarts to the bushel.

(b) *Harwich*. — The scallop territory of Harwich covers an extensive area on the south side of the town, and in some places extends for a distance of from 2 to 3 miles out from shore. Usually the scallops are found, as in the last season (1907-08), outside the bar, at a distance of 3 miles from shore, where they can be taken only by dredging from sail or power boats. The intervening body of water sometimes contains a few scallops in a quantity to make a commercial fishery. The total area of the scallop grounds is about 3,200 acres. The bottom is mostly sandy, with patches of eel grass.

(c) *Dennis*. — The scallop grounds of Dennis and Yarmouth are common property for the inhabitants of both towns, while other towns are excluded from the fishery. The West Dennis scallopers fish mostly on the Yarmouth flats at the mouth of Parker River, and between Bass and Parker rivers on the shore flats. There is also scalloping along the shore on the Dennis grounds. These grounds are for the "pushers." Dredging is carried on at Dennisport, and the boats cover a wide territory at some distance from the shore. The town possesses a large area, which either has scattering scallops or is well stocked one year and barren the next. Nearly 2,250 acres of available territory are included in the waters of the town. The flats, which are of sand with thick or scattering eel grass, according to the locality, afford a good bottom for scallops. Were it not for the eel grass, the scallops would perish by being washed on the shore by southerly winds.

(d) *Yarmouth*. — The scallop grounds of Yarmouth are on the south side of the town, on the flats which border the shore from Bass River to Lewis Bay. Part of the waters of Lewis Bay belong to the town of Yarmouth, and scallops are found over all this territory. The nature of the bottom is the same as at Dennis and Barnstable. The total area of scallop territory is estimated at 2,250 acres. The scallop grounds of Dennis are open to Yarmouth scallopers.

(e) *Barnstable*. — Although the scallop industry on the north coast of the town is extinct, it still flourishes as of old on the south coast. The bulk of the business is carried on here, and nearly all the shipments are made from Hyannis and Cotuit. The grounds of Cotuit are quite



small, extending over an irregular strip of 100 acres. The bottom is mostly muddy, and covered with patches of eel grass. All the rest of the bay, where the bottom is more suited for oyster culture, is taken up by grants. This scalloping area, although small, is free to the scallopers of Osterville, Cotuit, Marston's Mills and Hyannis, and even where heavily set it is soon fished out. The scallop territory near Hyannis comprises 2,700 acres, in the following localities: (1) Lewis Bay; (2) near Squaw's Island; (3) Hyannisport harbor; and (4) the shore waters. At Hyannisport small scallops are taken with "pushers" in the shallow water, while large scallops are taken by dredging in the other three localities. Scallops are found in different parts and in varying abundance each year.

(f) *Mashpee*. — The scallop territory of Mashpee lies in the Popponneset River and Bay, comprising at most 200 acres. For the last eight years there has been no scallop industry in the town. A few scallops are occasionally gathered for home consumption.

Buzzard's Bay. — The third section comprises the waters at the head of Buzzard's Bay, the most protected and perhaps the most favorably situated of the scalloping localities in respect to natural conditions. The warmth and excellent circulation of the water as it courses in and out of the numerous little bays and inlets are favorable to rapid growth, and render possible the production of the large scallop, averaging 2.73 inches, found in this section. The medium rise and fall of the tide (about 4 feet) and the eel-grass bottom give the scallops abundant protection in contrast to the exposed situation in other localities. In spite of these favorable surroundings great numbers of scallops perish from the severe winters and from the attacks of their natural enemy, the starfish. For seven years previous to the season of 1907-08 the scallop fishery had been a failure in these waters, said to have been due to the inroads of this pest, but since that date it has again become of importance. The scalloping territory comprises 11,100 acres and is situated in the towns of New Bedford, Fairhaven, Mattapoisett, Marion, Wareham, Bourne and Falmouth. The fishing is carried on almost wholly by dredging.

(a) *New Bedford*. — The scallop area comprises approximately 400 acres, principally in the Acushnet River and Clark's Cove.

(b) *Fairhaven*. — This town shares with New Bedford the scalloping grounds of the Acushnet River, and has in addition a much larger territory around Scouticut Neck and West Island. The grounds comprise about 2,500 acres, most of which is unproductive or productive only at intervals.

(c) *Mattapoisett*. — The scallop territory, comprising an area of 1,200 acres, much of which is open and exposed, is in general confined to the following localities: Nasketucket Bay, Brant Bay, Brant Island Cove, Mattapoisett harbor, Pine Neck Cove and Auecote Cove.



(d) *Marion*.—The scallop grounds of the town extend over an area of 1,500 acres, situated on both sides of Great Neck, and extending from the Wareham line to Aucoot Cove.

(e) *Wareham*.—Situated at the head of Buzzard's Bay, this town possesses a considerable water area which is suitable for scallops. The entire territory, embracing approximately 2,500 acres, extends in a southwesterly direction from Peter's Neck, including Onset Bay, to Abiel's buoy, and from there to Weweantit River. Scallops are also found in the Wareham River. Scallops are mostly found in the deep water, which makes dredging the only profitable method of scalloping in this locality.

(f) *Bourne*.—The available scalloping territory covers approximately 3,000 acres, extending from Buttermilk Bay along the whole coast of the town to Cataumet.

(g) *Falmouth*.—Scallops are found in Squeteague Pond, Wild harbor, North Falmouth and in West Falmouth harbor. Scallops are occasionally present in small quantities in Waquoit Bay, on the south shore of the town.

The Islands of Nantucket and Martha's Vineyard.—This section bears evidence of the protection of a fishery by nature and the ability of the inhabitants to foster a valuable industry. In both islands the natural conditions are such as to supply the maximum aid in the preservation of the fishery. The scallop territory, for the most part, lies in protected bays, Nantucket harbor, Cape Poge Pond and Vineyard Haven. Certain parts of the territory are exposed and subject to conditions unfavorable for the scallop, but the greater portion is well inclosed and favorably suited for regulating the distribution of "seed." The rise and fall of the tides is slight, not averaging more than 2 feet. A variety of bottom mostly covered with eel grass is found in all the localities, while the depth of water over the beds averages from 10 to 15 feet, rarely exceeding 25.

In this section, no matter how scarce the supply may be elsewhere in the State, the yield of scallops is constant. While there is more or less variation in the different years, extreme scarcity and superabundance, so common in the other sections, occur here but rarely, and the scallop supply from this locality is considered the most dependable in Massachusetts. The total area comprised in this section is 7,300 acres.

(a) *Nantucket*.—The grounds lie both in Nantucket harbor and in Maddequet harbor, on the west end of the island. The former of these is the larger and more important, as the fishery is near the town. When the scallops become scarce in Nantucket harbor, the scallopers adjourn to the fresher beds of Maddequet. Nantucket harbor contains approximately 3,000 acres of scallop territory; Maddequet and Muskeget, 1,500 acres.



(b) *Edgartown*.—The important grounds are in Cape Poge Pond and in Edgartown harbor, while occasionally beds of scallops, especially "seed," are found in Katama Bay. These grounds comprise an area of 2,000 acres, chiefly of grass bottom.

(c) *Vineyard Haven*.—The scalloping grounds of Tisbury are in the harbor at Vineyard Haven. Only Vineyard Haven fishermen make a business of scalloping here. The scallop grounds comprise an area of 800 acres.

The Present Industry in Massachusetts.

In considering the scallop industry the following points should be noted: (1) It has been necessary to record as scallop area any grounds where scallops have ever been found, in spite of the fact that only a portion of this total area is in any one year productive. (2) The boats engaged in the scallop fishery are but transitory capital, which is utilized, outside of the scallop season, in other fisheries. (3) The quahaug and scallop fisheries in many towns supplement each other, as the same men and boats are engaged in both industries. (4) The length of the season varies in the different localities. In New Bedford and Fairhaven the scallops are mostly caught in a few weeks, as many boats enter the business temporarily. This necessarily gives an excess of invested capital and a small production. In these two towns the number of scallop licenses are recorded, as showing the number of men engaged in the fishery, while as a fact but a small part of these are steadily engaged in the industry.



THE SCALLOP FISHERY

TOWN.	Number of Men.	BOATS.		EXTRA DORIES.		Value of Gear.	PRODUCTION, 1907-1909.		Area of Scallop Grounds (Acres).
		Number.	Value.	Number.	Value.		Gallons.	Value.	
Barnstable,	39	23	\$8,000	-	-	\$575	1,580	\$2,004	2,800
Bourne,	38	30	15,000	-	-	1,300	12,000	15,720	3,000
Chatham,	107	35	10,650	61	\$1,430	1,185	34,615	45,345	2,000
Dennis,	30	9	4,230	9	180	368	2,950	3,865	2,250
Edgartown,	39	26	8,000	-	-	550	17,000	22,270	2,000
Fairhaven,	73 1	50	12,500	-	-	1,500	1,300	1,708	2,000
Harwich,	12	7	2,350	-	-	280	2,170	2,843	3,200
Marion,	44	16	5,900	24	250	580	7,000	9,170	1,500
Matapoisett,	22	19	6,900	-	-	760	5,000	6,550	1,200
Nantucket,	99	47	13,250	20	500	700	20,245	26,189	4,500
New Bedford,	38 1	20	5,000	-	-	600	700	917	400
Tisbury,	20	8	3,000	6	90	800	3,000	3,680	800
Wareham,	45	36	10,800	-	-	1,900	10,000	13,100	2,500
Yarmouth,	41	15	3,750	10	200	475	8,000	10,480	2,250
Total,	647	341	\$108,730	180	\$2,660	\$10,573	125,510	\$164,486	30,900

1 Licenses.

The History and Development of the Scallop Industry.

In considering the rise of a fishing industry, it is often difficult to state exactly the year when the industry started, as there are differences of opinion as to how large a fishery should become before it could be justly considered an industry. The scallop fishery has existed for years, but did not become an established industry of the Commonwealth before the year 1872. At that time there was scarcely any demand for scallops and the catch was marketed with difficulty. Since then the market for the scallop has steadily increased, until the supply can hardly meet the popular demand.

It seems almost incredible that the scallop as an article of food should once have been scorned and practically unknown. In former years the majority of people looked upon the highly colored shellfish, with its beautiful shell, as poisonous and unfit for the table, in the same manner as our country fathers considered the "love apple," now the tomato, as only an ornament for the garden. Popular taste and opinion have changed, and the formerly despised scallop is now considered as an important part of our sea food. What has been true with the scallop applies equally well in regard to our future attitude towards sea food; many species of fish and shellfish now considered as unwholesome will, in the years to come, be considered as articles of food.

In early colonial days the scallop was frequently mentioned by the writers of that period, possibly because the attractive appearance of the fan-like shell rendered it a conspicuous object on the beaches, and possibly because the scallop shell had been from the time of the Crusades of emblematic significance. The first use of the scallop was as fertilizer. When blown ashore in quantities, the farmers occasionally came with their carts and carried the decaying shellfish to spread over their inland farms. The next step in the popularization of the scallop was made by the domestic animals, such as cats, dogs, pigs, etc., as the inhabitants let the swine obtain their living from the flats and shellfish. No records have been found by the writer to show that the Indians taught the colonists the use of the scallop as an article of food, or that they were conversant with its use for that purpose in England. So in all probability the edible qualities of this mollusk gradually became known.

Previous to 1874 the industry was of little importance as the scallops were only gathered by hand or taken from the shallow water with dip nets and rakes. This date marks the introduction of the dredge on Cape Cod, which revolutionized the industry by opening new territory and increasing the ease of capture in the deep water. From this time the fishery steadily increased and the market correspondingly widened.

In Buzzard's Bay the fishery first started at New Bedford in the Acushnet River in 1870, furnishing between 1870 and 1879 a winter living for 15 men. From this locality the fishery spread rapidly in 1879



among the other shore towns on the north side of the bay. In 1879 several boats from New Bedford commenced dredging in Wareham waters, and the townspeople soon followed the example of the invaders. From 1879 to 1899 the fishery became of importance as a winter industry in the upper waters of the bay, and flourished until 1899, when it became commercially extinct except at New Bedford and Fairhaven. The fall of 1907 furnished a revival of the fishery, which has every indication of becoming permanent.

The industry first started on Cape Cod at Hyannis in 1874, where a number of men entered the new business; and for several years the production increased rapidly, with the opening of new territory and improved methods of capture. The other towns on the south side of the Cape entered in the new fishery at the same time and with similar success. From that time on the fishery has been a variable factor in the towns of this section, depending upon the supply.

On the islands the fishery began at Edgartown in 1875 and at Nantucket in 1883, and in both cases the supply has been fairly constant, a poor or successful season depending more on the market price and the abundance in the rest of the State than on the local supply.

While the natural supply has remained the same or has evidenced a decline in certain localities, the value of the industry as a whole, both in regard to the number of men engaged, capital invested and the market returns, has steadily increased. The price of scallops varies from year to year and at different parts of the same season; but in spite of the irregularity of the catch the price per gallon has increased threefold (from 50 cents to \$1.50) since 1880, showing the increasing importance of the fishery.

The Decline.

The most important questions which first come to mind when considering the scallop industry of to-day are these: (1) Has there been any decline in the industry? If so, how extensive? (2) What are the causes of the decline?

Extent of the Decline. — There is no question but that the industry as a whole has declined. This decline has made itself manifest, especially in certain localities, *e.g.*, Buzzard's Bay, where until 1907 the entire fishery, except at New Bedford and Fairhaven, had been extinct for seven years. Along the south side of Cape Cod, at Edgartown and Nantucket, the supply has, on the average, remained the same. Of course there is varying abundance each year, but as a whole the industry in these localities can hardly be said to have declined. On the other hand, on the north side of Cape Cod we find a noticeable decline. A scallop fishery no longer exists at Plymouth, Barnstable harbor, Wellfleet and Provincetown, though twenty-five years ago these places possessed a slight industry.

So we have to-day in Massachusetts three localities, two of which show

a marked decline in the scallop fishery, while the other shows some improvement. Of the two depleted areas, the one (north of the Cape) may never revive the industry; the other (Buzzard's Bay) gives indications that the industry can once more be put on a profitable footing. The only thing necessary is perpetual precaution on the part of the fishermen in order to prevent this decline.

Causes of the Decline. — The causes of the decline of this industry can be grouped under three heads: (1) natural enemies; (2) overfishing by man; (3) adverse physical conditions. In the last instance the severe winters, storms, anchor frost, etc., bring destruction upon the scallops, especially during early life.

The Fishery.

The Season. — There is considerable diversity of opinion among the scallopers as to when the scallop season should open. Some advocate November 1 as the opening date, instead of October 1, as the present law reads; and many arguments are put forth by both sides.

The class of fishermen who desire November 1 are those who are engaged in other fishing during the month of October, and either have to give it up or lose the first month of scalloping. Naturally, they wish a change, putting forth the additional argument of better prices if the season begins later. The scalloper who is not engaged in other fishing of course desires the law to remain as it is at the present time, claiming that the better weather of October gives easier work, more working days, and allows no chance of loss if the winter is severe.

Under the present law, the town can regulate the opening of its season to suit the demands of the market and the desire of the inhabitants. This does away with the necessity of any State law on this point, which, under the present system of town control, would be inadvisable.

The general opinion of the fishermen is in favor of the present date, October 1. As nearly as could be determined, about 75 per cent. favor October 1 and 25 per cent. November 1. This sentiment is divided by localities, as more men were in favor of November 1 at Nantucket and Edgartown than on Cape Cod and Buzzard's Bay, where very few favored a change.

The Methods. — The methods of scalloping follow the historical rise of the fishery. As the industry grew more and more important, improvements became necessary in the methods of capture, and thus, parallel with the development of the industry, we can trace a corresponding development in the implements used in the capture of the scallop.

(a) *Gathering by Hand.* — When the scallop was first used as an article of food, the primitive method of gathering this bivalve by hand was used. This method still exists on the flats of Brewster, and often

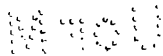
in other localities after heavy gales wagons can be driven to the beach and loaded with the scallops which have been blown ashore.

(b) *Scoop Nets*.—The hand method was not rapid enough for the enterprising scallopers, and the next step in the industry was the use of scoop nets, about 8 inches in diameter, by which the scallops could be picked up in the water. These nets were attached to poles of various lengths, suitable to the depth of water. "This method," writes Ingersoll (8), "was speedily condemned, however, because it could be employed only where scallops are a foot thick and inches in length, as one fisherman expressed it."

(c) *The Pusher*.—The next invention was the so-called "pusher." The "pusher" consists of a wooden pole from 8 to 9 feet long, attached to a rectangular iron frame 3 by 1½ feet, upon which is fitted a netting bag 3 feet in depth. The scalloper, wading on the flats at low tide, gathers the scallops by shoving the "pusher" among the eel grass. When the bag is full, the contents are emptied into the dory and the process repeated. The scallopers who use the "pusher" go in dories, which are taken to the various parts of the scalloping ground and moved whenever the immediate locality is exhausted. This method is in use to-day, but is applicable only to shallow flats, and can be worked only at low tide, where dredging is impossible. It is hard work, and not as profitable as the better method of dredging. This method of scalloping is used chiefly at Chatham, Dennis and Yarmouth; occasionally at Nantucket and other towns.

(d) *Dredging*.—The greater part of the scallop catch is taken by dredging, which is the most universal as well as the most profitable method. The dredge, commonly pronounced "drudge," consists of an iron framework about 3 by 1½ feet, with a netting bag attached, which will hold from one to two bushels of scallops. Catboats, carrying from 6 to 10 dredges, are used for this method of scalloping. These boats, with several "reefs," cross the scallop grounds pulling the dredges, which hold the boat steady in her course. A single run with all the dredges overboard is called a "drift." The contents of all the dredges is said to be the result or catch of the "drift."

When the dredges are hauled in they are emptied on what is known as a culling board. This board runs the width of the boat, projecting slightly on both sides. It is 3 feet wide, and has a guide 3 inches high along each side, leaving the ends open. The scallops are then separated from the rubbish, such as seaweed, shells, mud, etc., while the refuse and seed scallops are thrown overboard by merely pushing them off the end of the board. Each catch is culled out while the dredges are being pulled along on the back "drift," and the board is again clear for the next catch. The culled scallops are first put in buckets and later transferred either to bushel bags or dumped into the cockpit of the boat.



Two men are usually required to tend from 6 to 8 dredges in a large catboat, but often one man alone does all the work. This seems to be confined to localities, as at Nantucket nearly all the catboats have two men. At Edgartown the reverse is true, one man to the boat, though in power dredging two men are always used.

Several styles of dredges are used in scalloping, as each locality has its own special kind, which is best adapted to the scalloping bottom of that region. Four different styles are used in Massachusetts, two of which permit a subdivision, making in all six different forms. Each of these dredges is said by the scallopers using them to be the best; but for all-round work the "scraper" seems the most popular.

(1) *The Chatham or Box Dredge.*—As this dredge was first used in Chatham, the name of the town was given to it to distinguish it from the other styles. At the present time its use is confined to Chatham and the neighboring towns of the Cape. With the exception of a very few used at Nantucket, it is not found elsewhere in Massachusetts.

The style of the box dredge is peculiar, consisting of a rectangular framework, 27 by 12 inches, of flat iron 1 by $\frac{1}{4}$ inches, with an oval-shaped iron bar extending back as a support for the netting bag, which is attached to the rectangular frame. To the side of the rectangular frame is attached a heavy iron chain about 4 feet long, to which is fastened the drag rope.

(2) *The Scraper.*—As can be seen by the illustration, this style of dredge consists of a rigid iron frame of triangular shape, which has a curve of nearly 90° at the base, to form the bowl of the dredge. Above, a raised crossbar connects the two arms, while at the bottom of the dredge a strip of iron 2 inches wide extends from arm to arm. This strip acts as a scraping blade, and is set at an angle so as to dig into the bottom. The top of the net is fastened to the raised crossbar and the lower part to the blade.

The usual dimensions of the dredge are: arms, $2\frac{1}{2}$ feet; upper crossbar, 2 feet; blade, $2\frac{1}{2}$ feet. The net varies in size, usually holding about a bushel of scallops, and running from 2 to 3 feet in length. Additional weights can be put on the crossbar when the scalloper desires the dredge to scrape deeper. A wooden bar, 2 feet long, buoys the net.

Two styles of this dredge are in use. At Nantucket the whole net is made of twine, while at Edgartown and in Buzzard's Bay the lower part of the net is formed of a netting of iron rings, the upper half of the net being twine. The iron rings are supposed to stand the wear better than the twine netting. This difference seems to be merely a matter of local choice. The "scraper" is perhaps the dredge most generally used, as, no matter what style is in use, a scalloper generally has a few "scrapers" among his dredges.

(3) *The "Slider."*—The principle of the "slider" is the reverse

of the "scraper," as the blade is set either level or with an upward incline, so the dredge can slide over the bottom. This dredge is used on rough bottom and in places where there is little eel grass. In some dredges the blade is rigid, but in the majority the blade hangs loose.

The "slider" used at Edgartown differs from the "scraper" by having perfectly straight arms and no curved bowl, the blade being fastened to the arms in a hook-and-eye fashion. The dimensions of this dredge are the same as those of the "scraper," although occasionally smaller dredges are found.

(4) *The "Roller" Dredge.* — This style of dredge is used only in the town of Mattapoisett, where the scallopers claim it is the most successful. The dredge is suitable for scalloping over rough ground, as the blade of the dredge is merely a line of leads, which roll over the surface of the ground gathering in the scallops.

The dredge consists of an oval iron frame, 32 by 20 inches, which acts as the arms, and is attached to another iron frame, 32 by 3 inches. The blade of the dredge consists of a thin rope with attached leads. The net is made wholly of twine, and is about 2½ feet long.

Outfit of a Scalloper. — The average invested capital of the scalloper can best be given for two classes, — the boat fisherman and the dory fisherman: —

<i>Boat Fisherman.</i>		<i>Dory Fisherman.</i>	
Boat,	\$500 00	Dory,	\$20 00
Dory,	20 00	Oars,	1 50
Six dredges,	25 00	Pusher,	2 50
Rope and gear,	25 00	Shanty,	25 00
Culling board,	2 00		—————
Incidentals,	3 00	Total,	\$49 00
Shanty,	50 00		
	—————		
Total,	\$625 00		

Scalloping with Power Boats. — The season of 1907 has witnessed in Massachusetts the first use of auxiliary power in the scallop fishery. At Edgartown the main part of the scalloping is now done by power, which, in spite of the additional expense of 5 gallons of gasoline per day, gives a proportionately larger catch of scallops. The Edgartown scallopers claim that their daily catch, using power, is from one-third to one-half better than under the old method of dredging by sail. Not only can they scallop when the wind is too light or too heavy for successful scalloping by sail, but more "drifts" can be made in the same time. A slight disadvantage of scalloping with power is the necessity of having two men, as the steering of the power boat demands much closer attention than the sail boat, which is practically held to a fixed course by the dredges. A power boat for scalloping possesses only the

disadvantage of additional cost; but it is only necessary to look forward a few years, when expedition rather than cheapness will be in demand, to a partial revolution in the present methods of scalloping, whereby the auxiliary catboat will take the place of the sail boat in the scallop fishery.

Preparing the Scallop for Market. (a) The "Eye."—The edible part of the scallop is the large adductor muscle. The rest of the animal is thrown away, though in certain localities it is used as fish bait and in others for fertilizer. Why the whole of the animal is not eaten is hard to say. Undoubtedly all is good, but popular prejudice, which molds opinion, has decreed that it is bad, so it is not used as food. This is perhaps due to the highly pigmented and colored portions of the animal. Nevertheless, there is a decided possibility that in the future we shall eat the entire scallop, as well as the luscious adductor muscle.

The adductor muscle is called by the dealers and fishermen the "eye," a name given perhaps from its important position in the animal, and its appearance. The color of the "eye," which has a cylindrical form, is a yellowish white.

(b) *The Shanties.*—The catch of scallops is carried to the shanty of the fisherman, and there opened. These shanties are usually grouped on the dock, so the catch can be readily transferred. Inside of these shanties, usually 20 by 10 feet or larger, we find a large bench 3 to 3½ feet wide, running the length of the shanty, and a little more than waist high. On these benches the scallops are dumped from the baskets or bags, and pass through the hands of the openers. Under the bench are barrels for the shells and refuse.

(c) *The Openers.*—The openers are usually men and boys, though occasionally a few women try their hand at the work. Of late years there has been a difficulty in obtaining sufficient openers, and the scallopers often are forced to open their own scallops. The openers are paid from 20 to 30 cents per gallon, according to the size of the scallops. One bushel of average scallops will open 2½ to 3 quarts of "eyes." An opener can often open 8 to 10 gallons in a day, making an excellent day's work. The price now paid is more than double that paid in 1880, which was 12½ cents per gallon. Some openers are especially rapid, and their deft movements cause a continual dropping of shells in the barrel and "eyes" in the gallon measure.

(d) *Method of opening the Scallop.*—The opening of a scallop requires three movements. A flat piece of steel with a sharp but rounded end, inserted in a wooden handle, answers for a knife. The scallop is taken by a right-handed opener in the palm of the left hand, the hinge-line farthest away from the body, the scallop in its natural resting position, the right or smooth valve down. The knife is inserted between the valves on the right-hand side. An upward turn with a cutting motion is given, severing the "eye" from the upper valve, while

a flirt at the same moment throws back the upper shell. The second motion tears the soft rim and visceral mass of the scallop and casts it into the barrel, leaving the "eye" standing clear. A third movement separates the "eye" from the shell and casts it into a gallon measure. Frequently the last two movements are slightly different. The faster openers at the second motion merely tear off enough of the rim to allow the separation of the "eye" from the shell, and on the third movement cast the "eye" in the measure, while the shell with its adhering soft parts is thrown into the refuse barrel. These last two motions can hardly be separated, so quickly are they accomplished.

(e) *Shipment.*—The kegs in which the scallops are shipped cost 30 cents apiece, and contain about 7 gallons. A full keg is known as a "package." The butter tubs are less expensive, but hold only 4 to 5 gallons. Indeed, anything which will hold scallops for shipment is used to send them to market.

When the scallops get to the market they are strained and weighed, 9 pounds being considered the weight of a gallon of meats. In this way about 6 gallons are realized from every 7-gallon keg. With the improved methods of modern times scallops can be shipped far west or be held for months in cold storage, for which purpose unsoaked scallops are required. Certain firms have tried this method of keeping the catch until prices were high, but it has not been especially successful.

(f) *Market.*—One of the greatest trials to the scallop fisherman is the uncertainty of market returns when shipping. He does not know the price he is to receive; and, as the price depends on the supply on the market, he may receive high wages or he may get scarcely anything. The wholesale market alone can regulate the price, and the fisherman is powerless. While this is hard on the scalloper, it does not appear that at the present time anything can be done to remedy the uncertainty of return. The scallop returns from the New York market are usually higher than from the Boston market. The result of this has been to give New York each year the greater part of the scallop trade, and practically all the Nantucket and Edgartown scallops are shipped to New York.

Either from a feeling of loyalty, or because the market returns are sooner forwarded, or because the express charges are less, Cape Cod still ships to the Boston market, in spite of the better prices offered in New York. Why so many Cape scallopers should continue to ship to Boston, and resist the attractions of better prices, is impossible to determine, and appears to be only a question of custom.

(g) *The Price.*—The price of scallops varies with the supply. The demand is fairly constant, showing a slight but decided increase each year. On the other hand, the supply is irregular, some years scallops being plentiful, in other years scarce.

The Food Value of the Scallop.

The large adductor muscle is the only part of the scallop which is used for food at the present day, as the rest of the soft parts are considered non-edible. The adductor muscle occupies the center of the shell and by reason of its conspicuous position has been given the name of "eye" by the fishermen. Less frequently it is spoken of as the "heart." From the standpoint of the consumer and the retail dealer the "eye" is the object of importance, and the word scallop is applied in such a way that many people believe that the little white cube comprises the whole animal. The "eye" can best be likened to the finished product of manufacture as it passes into the purchaser's hands. Therefore, it is to the advantage of the consumer to know (1) the amount of nutriment of the scallop compared with other articles of food, both shellfish and meats; (2) the effects of "soaking" scallops; (3) the amount of waste and the percentage of actual food in scallops from the different localities in the Commonwealth.

Food Value.—As a food the scallop stands ahead of all the other shellfish, containing much more nourishment than the oyster. The following figures are from the tables of Professor Atwater, rearranged by C. F. Langworthy (14):—

	Refuse, Bone, Skin, etc. (Per Cent.).	Salt (Per Cent.).	Water (Per Cent.).	Protein (Per Cent.).	Fat (Per Cent.).	Carbohydrates (Per Cent.).	Mineral Matter (Per Cent.).	Total Nutrients (Per Cent.).	Fuel Value per Pound. (Per Cent.).
Oysters, solids, . . .	-	-	88.3	6.1	1.4	3.3	.9	11.7	235
Oysters, in shell, . . .	82.3	-	15.4	1.1	.2	.6	.4	2.3	40
Oysters, canned, . . .	-	-	85.3	7.4	2.1	3.9	1.3	14.7	300
Scallops,	-	-	80.3	14.7	.2	3.4	1.4	19.7	345
Soft clams, in shell, . . .	48.6	-	48.4	4.8	.6	1.1	1.5	8.0	135
Soft clams, canned, . . .	-	-	84.5	9.0	1.3	2.9	2.3	15.5	275
Quahaugs, removed from shell.	-	-	80.8	10.6	1.1	5.2	2.3	19.2	340
Quahaugs, in shell, . . .	68.3	-	27.3	2.1	.1	1.3	.9	4.4	65
Quahaugs, canned, . . .	-	-	83.0	10.4	.8	3.0	2.8	17.0	285
Mussels,	49.3	-	42.7	4.4	.5	2.1	1.0	8.0	140
General average of mol- lusks (exclusive of canned).	60.2	-	34.0	3.2	.4	1.3	.9	5.8	100

In the following table the scallop is compared with the chemical analysis of various meats in their food stuffs. The figures for the meats

are taken from Howell's "Physiology" (13). The comparative prices were obtained in the Boston markets on Feb. 18, 1910.

	IN 100 PARTS (PER CENT.).					Wholesale Price per Pound (Cents).
	Water.	Protein.	Fat.	Carbo-hydrate.	Ash.	
Scallop "eyes,"	80.30	14.70	.20	3.40	1.40	19½
Beef, moderately fat, . . .	73.03	20.96	5.41	.46	1.14	9¾
Veal, fat,	72.81	18.68	7.41	.07	1.33	12½
Mutton, moderately fat, . .	75.99	17.11	5.77	-	1.33	10
Pork, lean,	72.57	20.05	6.81	-	1.10	14½

"Soaking."—The "eye" is frequently put through a process familiarly known as "soaking" before it is sent to market. If not done by the fishermen it is completed by the dealer, in order to tempt the purchaser with a beautiful white, plump "eye" instead of a small yellow-colored specimen. Undoubtedly fishermen and dealers would willingly sell unsoaked scallops at a proportionate price the moment the market demands them; but the consumer, through ignorance, prefers the large, nice-appearing "eyes," and thus unwittingly favors the practice.

From a practical standpoint "soaking" is a very simple affair, the "eyes" being placed in fresh water for several hours until they have absorbed sufficient water to increase their bulk about one-third. It has been noticed that whenever salt-water products are allowed to soak in fresh water an increase of bulk is found. This is due to a complicated change, the most prominent factor being osmosis, which causes a swelling of the tissues. The "eye" can be increased by this change to a gain of more than one-third its natural size; that is, 4½ gallons can be increased to 7 by judicious "feeding" with fresh water.

Two methods of swelling scallops are in use. When the scallops are shipped in kegs which usually contain 7 gallons, the following method is applied: 4½ to 5 gallons of "eyes" are placed in each keg, and are allowed to stand over night in fresh water; in the morning, before shipment, more water is added and the keg closed, and by the time of arrival to the New York or Boston market the scallops have increased to the full amount of 7 gallons. The second method of "soaking" is slightly more elaborate. The "eyes" are spread evenly in shallow wooden sinks, 5 by 3 feet, with just enough fresh water to cover them, and left over night. In the morning a milky fluid is drawn off, and the "soaked" scallops are packed for market in kegs or butter tubs.

The process of "soaking" was not instituted until some years after the start of the scallop industry. In 1886 Ingersoll (8) reports that scallops were not being "soaked" in Rhode Island and Connecticut. Dr. Hugh M. Smith (12) attributes the beginning of soaking to the fact

that the small Cape scallops could not compete in the Boston market with the larger Maine scallops (deep sea), and that the fishermen found it necessary to increase the size by swelling. If this were the cause, the fishermen soon found it decidedly to their advantage to continue the process of selling "watered stock."

A change has taken place in the appearance of the scallop a few hours after soaking. The small yellow or pinkish "eye" of the freshly opened scallop has taken on a white, plump appearance, adding greatly to its salable qualities. On the other hand, the fine flavor and freshness have disappeared, "soaked" out, so to speak, and the transformed scallop lacks many of the qualities which endear it to the heart of the epicurean. Considerable loss in nourishment has taken place, although exact figures have not been conclusively obtained by experiment, and the scallop spoils much sooner than the unsoaked. If kept too long the absorbed water is given off and the scallop shrinks back to its original size, a process which is more quickly accomplished on the frying pan, where the "soaked" scallop rapidly shrivels. While too much cannot be said to discourage the "soaking" of scallops and to educate the public to demand the real article, it can be fairly stated that the process, although producing an inferior article of food, is not detrimental to the public health as long as proper sanitary precautions are taken by having the surroundings hygienic and by using pure water.

The practice of "soaking" will only come to an end when the public refuse to buy anything but "dry" scallops, and only till then, unless special legislation is enforced, will "soaked" scallops be taken from the market. At the present time, if the wholesale dealers uniformly demanded "unsoaked" scallops from the fishermen, and increased the price, they would be able to get their shellfish unsoaked.

Food and Waste.—The determination of the amount of food and waste in the scallop was undertaken with scallops from six scalloping towns, comprising the three sections of Buzzard's Bay, Cape Cod and the islands. In this work the "eye" was considered the only edible part of the animal. Four sizes, 55 millimeters, 60 millimeters, 70 millimeters and 75 millimeters were used. Ten scallops of each size were dissected, and the weight of the different parts recorded.

(a) *The Food Value of the Average Scallop.*—The "eye" or edible portion constitutes but a small part of the entire scallop. By weight the actual food in a scallop of 65 millimeters ($2\frac{5}{16}$ inches), the average from all the determinations, is only 17.77 per cent. of its weight. Thus, in order to get 18 pounds of "eyes" (2 gallons) it would be necessary to procure 100 pounds of living scallops.

The average scallop (Fig. 82) is made up as follows: total weight, 1.5 ounces, or 100 per cent.; total non-edible part, 1.23 ounces, or 82.23 per cent. (includes both shell and non-edible soft part); non-edible soft

parts, .49 of an ounce, or 32.8 per cent.; shell, .74 of an ounce, or 49.43 per cent.; actual food, .27 of an ounce, or 17.77 per cent. Considering merely the soft parts of the scallop, the proportion of food and waste is much closer. The "eye" is by weight 35 per cent. of the soft parts, while the non-edible soft parts constitute the remaining 65 per cent.

(b) *The Non-edible Parts.* — The non-edible parts of the scallop can be divided into two classes, (1) the shell or hard portion, which is necessarily waste except for certain uses common to all shellfish, (2) the viscera of the scallop, or all parts except the "eye." The latter is the non-edible part proper; as in other shellfish these parts are utilized for food.

(1) *The Shell.* — The shell impregnated with lime salts necessarily makes up a good portion, about one-half, of the total weight. However, it cannot be considered waste except in a non-edible sense, as the scallop shell is found useful in several ways. (a) Oyster planters buy large quantities of shells for cultch to catch the oyster set, as the fragile nature is most serviceable in separating the clusters of young oysters. The average price runs from 3 to 5 cents per bushel. The greater part of the shell heaps are utilized for this purpose. (b) On Cape Cod, shell roads and walks are sometimes made with scallop shells. (c) Work baskets, pin cushions and various ornaments of the house are decorated with scallop shells. (d) Within the last few years scallop shells bound together with ribbon and containing miniature photographic views, for souvenir postal cards, have been put on the market by Boston firms, who purchased the cleaned shells from the scallopers at the rate of \$6 per barrel. Only the lower or bright colored valve is used.

(2) *The Soft Parts.* — The non-edible part or body of the scallop forms 32.8 per cent. by weight of the total scallop. While not utilized for food at the present time, although there is no reasonable objection except custom and prejudice, it is made use of for (a) fish bait, either fresh or salted; (b) fertilizer. The probable reason why this wholesome flesh is not made use of as food is because of the brilliant coloring of the mantle and its tough appearance. Other shellfish, such as the clam, quahaug and oyster, are eaten entire, and there is no good reason why the scallop should not be taken in the same way.

(c) *The Size of the "Eye."* — The relative size of the "eye" increases with the size of the scallop, as its percentage by weight is slightly greater in large scallops. The percentage by weight for a 60-millimeter scallop is 17.47 per cent.; for a 65-millimeter, 17.87 per cent.; for a 70-millimeter, 17.97 per cent., while the ratio of shell and body does not seem to change. The actual weight of the "eye" varies in the different localities, some showing as much as one-fourth more weight for the same sized scallop. In percentage the Buzzard's Bay district led, averaging about 18.18 per cent., with 18.70 per cent. high at New Bedford, while Chatham and Nantucket gave only 17.20 per cent. and 16.67 per

cent. respectively. This fact does not indicate anything about the food value of the scallops from these localities, but is merely cited to show the variation in the weight of the "eye," and that Buzzard's Bay scallops should yield a greater return per bushel. Beside this variation, two conditions influence the size and weight of the "eye": (1) the season or time of year, as the "eye" is reported by the fishermen "to turn out more to the bushel" when the cold weather comes on; (2) the age of the scallop, as the "eye" of a two-year-old scallop (one that has passed the period of allotted life) is looser in texture and weighs less.

(d) *Weight of Shell.*—Differences in the weight of the shell for scallops of the same size occur in different localities. The weight of the shell is determined by two factors, (1) the rapidity of growth; (2) the amount of lime salts in the water. These factors are rarely the same for any two localities, and naturally variations would be expected in the weight of the shell. The average weight of the shell for a 65-millimeter scallop is 21.9 grams, yet in six localities we find the weights ranging anywhere between 20 and 23 grams.

The Laws.

The question of scallop legislation has attained considerable importance during the past four years, particularly in regard to the "seed" scallop. During this period three laws have been passed, with the ostensible purpose of protecting the "seed," but have proved far from satisfactory both from the standpoint of the fishermen and the officials employed by State and towns for their enforcement. The reasons for the unsatisfactory state of affairs resulting from this frequent change in legislation are twofold: (1) it is almost impossible to give a comprehensive legal definition of a "seed" scallop; (2) a general law necessarily cannot suit all localities. The present law of 1910, founded on the legislative experience of past years, should prove satisfactory to the State as a whole.

In the early days the scallop was not considered worthy of legislation, as it had no market value, and was generally considered as a poisonous or non-edible shellfish. With the opening of the market arose the necessity of regulating the fishery, and legislation of a restrictive character was enacted.

Previous to 1874 the scallop came under the general acts included in the term shellfish, with the clam, oyster and quahaug. The general acts were of several kinds, (1) town regulation; (2) permits; (3) seizure in vessels; and (4) protection of the shellfisheries by limiting the catch, place and time of taking.

In 1874 occurs the first mention of the word scallop in a legislative act "to regulate the shellfisheries in the waters of Mount Hope Bay and its tributaries," whereby the selectmen of the towns bordering on Mount Hope Bay were permitted to grant licenses for the cultivation

of clams, quahaugs and scallops, and other shellfish to any inhabitant. It seems strange that such an advanced and beneficial act should have been passed at that early period, as it was clearly before its time, and unsatisfactory, as is shown by its repeal the following year. It is only within the last year that similar legislation has been passed for the quahaug. Although it is improbable that the cultivation of scallops will ever become extensive, it is only the question of a short time when the cultivation of all shellfish will be legalized.

The second mention of the word scallop is found in the act of 1880, by which the Commonwealth gave to the towns and cities their present oversight of the shellfisheries and full power "to control and regulate the taking of eels, clams, quahaugs and scallops." This act was later amended by the Acts of 1889, but the general terms of the act were not changed, and the present law is but slightly different. Town control as applied to scallop fishery has its advantages and disadvantages, and the wisdom of State control is a debatable question. The present system is to the advantage of certain towns and a loss to the fishermen of the other towns and to the general consumer, since town restrictions prohibit the taking of shellfish by outsiders. Owing to the short life of the scallop the adults left untaken, occasionally in large numbers at the end of a season, perish before another year. More men could have been given employment and a greater supply furnished the consumer if the large beds had been opened to other fishermen besides townsmen. As matters exist, the majority of fishermen seem satisfied with the present system of town control, and until public opinion is favorable to the best utilization of the scallop fishery, State control is not desirable.

Special legislation for the scallop fishery was first enacted in 1885 by an act which limited the catch to 25 bushels a boat per day, the first restrictive legislation upon the scallop fishery. Since that time, within twenty-six years, eight State and seven special acts for towns, in all fifteen laws, have been enacted, all but one of which have been for the regulation of the fishery as regards permits, season, catch and town supervision. The only exception was an act empowering the Commissioners on Fisheries and Game to make an investigation of the spawning and propagation of the scallop. These laws illustrate the following features:—

Daily Limit to the Catch.—The act of 1885 placed a limit of 25 bushels per day for each boat, making no allowance as to the size of the boat. No record of the repeal of this act has been found, and it remained practically an unknown law until 1910, when a limit of 10 bushels per day for each person was passed.

The Season.—Previous to the act of 1885, which made a closed season between April 15 and September 1, there had been no restriction upon the time of capture. The primary object of this act was due to a desire to protect the scallop during its breeding season, and because the winter

months were the best suited for handling and marketing the "eyes." In 1887 and in 1896 the closed season was changed to April 1 to October 1, which proved satisfactory until 1909, when the experiment was tried of shortening it to September 1. In 1910 the act of 1909 was repealed, at the petition of the scallop fishermen of the Commonwealth, and the old limits (April 1 to October 1) resumed. The acts of 1885 and 1887 prohibited the capture, sale and export of scallops during the closed season, while that of 1896 replaced the word export by "have in possession." In 1909 any inhabitant of the Commonwealth was permitted to gather by hand scallops for his own use at any season.

The Penalties. — The acts of 1885 and 1887 gave a maximum penalty of \$20, which was increased to \$50 by the act of 1896, which likewise established a minimum of \$20. The acts of 1907, 1909 and 1910 lowered this penalty to a minimum of \$5 and a maximum of \$20. Special acts for the towns of Buzzard's Bay, in 1888, 1892, 1893 and 1900, established a penalty of \$20 to \$100.

"Seed" Scallops. — Legislation for the protection of the "seed" scallop was first enacted in 1887, with maximum penalty of \$20 for each offence, which was increased to \$50 in 1896. Neither act in any way defined the term "seed" scallop. In 1906 a "seed" scallop was legally defined as a scallop under 2 inches, but a size limit proved unsatisfactory, owing to the great variation in size of young and adult scallops, and was replaced in 1907 by a detailed definition. This definition, although describing thoroughly the "seed" scallop, proved too cumbersome for legal use, and was simplified in 1909 to read merely "a well-defined growth line." The act of 1909 gave a leeway of 15 per cent. for the "seed" unavoidably taken, which made the law difficult to enforce and harmful to the fishery. This percentage was lowered to a nominal 5 per cent. in 1910. "Seed" scallop legislation has been the most troublesome, owing to the difficulty in adequately defining the term so that it will bear legal interpretation. As long as the scallop fishermen refuse to take the immature scallops, there is but little need of the rigid enforcement of the "seed" scallop law.

Town Laws. — Special acts for towns are somewhat different than the general State laws governing the fishery, as they merely apply to local waters and emphasize the powers already given by the general shellfish law of 1880 to the town officials. Special scallop laws apply to Nantucket, Wareham, Bourne, Marion, Rochester, Mattapoisett and Fairhaven, and are of two classes: —

(a) *Bait Regulation.* — Nantucket is the only town which is allowed to catch scallops for bait out of season, and here only from April 1 to May 15, according to an act of 1901, previous to which the limit was from April 1 to May 1 by the act of 1888.

(b) *Local Regulation by Permits.* — The selectmen of the towns above mentioned, except Nantucket, were empowered by special acts to

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issue permits for scalloping in whatever way they saw fit, and at whatever charge they deemed proper. A severe penalty of \$20 to \$100 fine was imposed for taking scallops without permits, except for family use and for bait. At the present time five towns, Fairhaven, Marion, Mattapoisett, Wareham, and Nantucket, issue special scalloping permits, while four others, Bourne, Chatham, Edgartown and Harwich, include the scallops under the general shellfish permits.

The local town laws which benefit the scallop industry are made each year according to the condition of the industry. Edgartown and Nantucket have perhaps the best-governed scallop industries. Laws requiring licenses, regulating the opening of the season and restricting at proper times the catch, so as to get the best market prices instead of overstocking the market when the prices are low, are to be recommended on account of their benefit to the scallopers.

Scallop Legislation.

No.	Date.	Kind.	Penalty.	Provisions.	Remarks.
1	1874	Special town.	\$5 to \$10 and \$1 per bushel.	License to plant scallops in Somerset, Swansea, Fall River.	Repealed 1875; word "scallop" mentioned.
2	1880	State, .	\$3 to \$50, . . .	Towns to regulate shellfisheries.	Word "scallop" mentioned.
3	1885	State, .	\$20,	25 bushels limit; closed season April 15 to September 1.	-
4	1887	State, .	\$20,	Seed scallops; closed season April 1 to October 1.	-
5	1887	Town, .	-	Nantucket allowed to take scallops for bait from April 1 to May 1.	-
6	1888	Town, .	\$20 to \$100, . .	Wareham and Bourne; permits.	-
7	1889	State, .	-	Town regulation, . . .	Modification of No. 2.
8	1892	Town, .	\$20 to \$100, . .	Marion, same as No. 6; permits.	-
9	1893	Town, .	-	Marion, Sec. 4 of No. 8, amended; Rochester, Mattapoisett.	Word "waters" added.
10	1893	Town, .	\$20 to \$100, . .	Fairhaven, same as No. 8, .	-
11	1896	State, .	\$20 to \$50, . . .	Seed prohibited; season April 1 to October 1.	Repetition of 1887 act, except penalty.
12	1900	Town, .	\$20 to \$100, . .	Mattapoisett, same as No. 8,	-
13	1901	Town, .	-	Nantucket; bait, April 1 to May 15.	-
14	1901	State, .	\$5 to \$10 for first offence; \$50 to \$100.	Capture prohibited in contaminated waters.	General shellfish; Fish and Game Commission powers.
15	1905	State, .	-	Investigation and report, .	-
16	1906	State, .	\$20 to \$50, . . .	"Seed" scallop, 2-inch limit,	Repealed, 1907.
17	1907	State, .	\$5 to \$20, . . .	"Seed" scallop, definition, .	Repealed, 1909.
18	1909	State, .	Not exceeding \$25.	Definition of "seed" scallop; 15 per cent. "seed"; capture by hand at any time.	Repealed, 1910.
19	1910	State, .	Not exceeding \$25.	Definition of "seed" scallop; 5 per cent. "seed"; capture by hand at any time; daily catch 10 bushels.	-

Method of Improving the Scallop Industry.

At the present age a fishing industry must show a steady development to keep pace with the increasing market, which is continually widening through better transportation facilities. Unfortunately, the tendency in the past has been, particularly in industries directly dependent upon natural resources, to meet the question of progression by increasing the yield through the improvements in implements and methods rather than by attempts to increase the natural supply, with the result that under the increased strain the natural resources have been seriously impaired and oftentimes completely destroyed. In these cases protective legislation has either been absent or based upon wrong principles. Examples of impaired resources are found in the natural oyster beds, the shad, sturgeon and alewife fisheries, the clam, quahaug and lobster industries, etc. In the future, fishing industries should be developed both by improved methods and by the increasing of the natural supply through propagation and protection, a work which is being carried on by federal and State fish commissions, and is gradually widening its scope to include all kinds of fisheries.

The scallop fishery presents peculiarities which differentiate it from other fishing industries, and a knowledge of which is essential in considering its improvement. (1) Protective legislation is principally confined to the "seed" scallop, or scallop less than one year old, although the new law of 1910 has placed a daily limit of 10 bushels for each man's catch. (2) The future welfare lies wholly in the hands of the fishermen and their proper respect for the preservation of the "seed" scallop. (3) Although there is plenty of room there is no great prospect for a wide expansion of the fishery, as there are few ways of artificially increasing the supply; but, on the other hand, if the spirit of protective legislation prevails there is but slight danger of a serious diminution. (4) The scallop fishery is peculiarly fortunate, as, unlike the clam and quahaug industries, it is unaffected by heavy fishing and needs but minimum care on the part of the fishermen to remain in excellent condition for years to come. Thus, while there are few possibilities for its development by increasing the natural supply, there is but slight danger of its permanent extinction.

Methods of Increasing the Natural Supply.—The possibilities of increasing the supply of scallops and thus improving the fishery will first be taken up. Many short-sighted fishermen would be opposed to the increasing of the supply, for they consider that the price would be lowered, and they would prefer a high price and small supply. But this idea is erroneous, as it takes no longer to dredge from thick beds than it does from depleted areas, and in view of the increasing popularity of the scallop the price would soon regain its former level. The consumer would be the gainer by the increased production, which would

tend to make scallops no longer a luxury but a part of the common diet. However, the fisherman need have no fears in this direction, as investigation has shown that there can be no great increase in the scallop supply, although many of the poor years can be avoided by proper foresight and by work along the lines here suggested.

The reason that the scallop supply can never be successfully increased is due, (1) to no practical means of artificial culture; (2) it was found by this department that money expended in propagating the embryos and young at the present time would be wasted, for the destructive agencies enumerated in chapter IV. would defeat any increase of the supply through successive years, one bad season undoing the work of several years and entailing a new start. If a severe winter killed all the spawning scallops in one locality, there would be the same scarcity of spawn, no matter how great the number of scallops. If such disasters were of rare occurrence the effect would not be so important, but destruction often occurs upon the shallow flats. Thus, under natural conditions there seems a maximum and minimum point of variation between which the scallop supply is constantly wavering. The supply can be somewhat increased and conditions improved by judicious transplanting from the exposed places, thus eliminating the adverse conditions.

(a) *Artificial Propagation.*—Artificial propagation may be of two kinds: (1) raising the young from the eggs; (2) catching the spat. So far our experiments have indicated that it is impossible to raise the young embryos in sufficient numbers for commercial hatching. Undoubtedly some benefit would result from the artificial fertilization of the eggs and the liberation of the young larvæ when they first begin to swim, as in nature there is a great loss through non-fertilization. But such a result is purely theoretical, as there is no way of determining the loss when the spawn is liberated. When kept in hatching tubs the majority die before they attain the shell stage. So far this method has proved unsatisfactory, and it is hardly believed that it can be put on a practical basis.

Spat collecting has already been considered under chapter IV., and it only is necessary here to state that for practical work spat collecting does not pay, as greater quantities of scallops can be obtained when small from the eel-grass flats than could be caught with extensive spat-collecting apparatus. Looking at it in one way the scallop supply would be increased so much by the scallops taken on the collectors, as they probably would not survive to set elsewhere, but such would be a "penny wise and pound foolish" method for the planter. If a scallop culturist found it impossible to obtain "seed" it might pay him to try spat collecting. This would only occur in rare instances, where scallops were not plentiful.

(b) *Artificial Culture.*—The question of raising scallops artificially for the market, and thus increasing the general supply, was one of the

first points considered in this investigation. Parallel work on the quahaug and clam showed that by individual culture or farming the general supply could be increased, barren area made to yield a harvest, the decline of the natural supply checked, and a profitable industry employing several times the number of men now engaged could be started. Conditions were found to be different with the scallop. There are serious limitations to individual cultivation. Scallops can swim and move for short distances, although they do not make the long migrations commonly credited to that species, and thus require penning. It was found that in a few places in the State the scallop could be cultivated by private persons. In every instance the locality of the prospective grant was in a small bay with a narrow outlet, situations so rarely existing that the idea of private scallop culture must be abandoned. Undoubtedly in the future, when grants are given for oysters, clams and quahaugs, they will be assigned under the broad term of "shellfish grants," and the scallops upon these bottoms will be considered as belonging to the grantee. In such cases the scallop is of secondary consideration, and in reality there will never be many true scallop grants.

(c) *Communal Culture.* — The scallop offers better opportunities for communal culture, *i.e.*, by towns. There is but one way now known of artificial propagation for the scallop industry, *i.e.*, by transplanting in the fall the abundant set from the exposed places to the deeper water before the "seed" is killed by the winter. It is merely assisting nature by preventing a natural loss, and in no sense can properly be termed propagation. It is a preventive, and money used in this way to preserve the scallop is well expended. Usually the set is abundant, and can be transferred in large numbers. This is the only practical method now known of increasing our scallop supply, though it is hoped in the future that other methods may be devised.

In connection with the above comes the question, if we can thus preserve scallops doomed to destruction, will it not be profitable to transplant scallops to places where the scalloping has been exterminated by various causes, and by means of these "seeders" furnish succeeding generations which may populate the barren areas? This plan is practical and feasible, and should be given due consideration. Why should not scallops be transplanted to the harbors of Buzzard's Bay to again restock these areas? Often the attempt might fail, but there is bound to be success if there is perseverance. The best time to plant scallops is in the fall, as a double service will be given: (1) preservation from destruction of the seed scallops; (2) furnishing spawn and young in the barren locality. Ingersoll (8) speaks of the restocking of Oyster Bay in 1880: —

In the spring of 1880 eel grass came into the bay, bringing young scallops [the eel grass carries the scallops attached to it by the thread-like byssus]; thus the abundance of that year was accounted for, though there had not been a crop before in that bay since 1874.

If such a restocking can be accomplished by nature, it can be done with more certain effect with man's assistance.

Restocking Barren Areas.— The practicability of restocking barren or depopulated areas is illustrated by the following: As few natural scallops were found in the Powder Hole, Monomoy Point, in 1906, and as it was desired to have the place well stocked for experimental work in 1907, 50 bushels of small scallops about the size of a quarter of a dollar were transplanted from the Common Flats at Inward Point in November, 1906. The result was an enormous set from these "spawners" in 1907, and the sandy bottom along the shores of the Powder Hole during the fall of 1907 and the summer of 1908 was thickly covered with the numerous 1907 set. The fishermen, who had been at Monomoy for years, remarked that it was the largest set that had ever been seen in the Powder Hole. It can be fairly asserted that the remarkable abundance was due to the bringing in of the spawners, and that this case is a striking illustration of the proper methods of assisting nature in increasing the scallop supply in any particular locality.

Our present town laws stand as obstacles to any restocking, as no town will give up the slightest part of its "seed" scallops to another town, thus making any practical tests impossible. Time will smooth away these difficulties, and the welfare of the community as a whole will be placed before the petty rivalry of towns.

Improving the Fishery.— The second means of improving the industry is to increase the efficiency of the fishery as regards methods, marketing, utilization of waste, etc. Perhaps the most important means of developing the fishery is to keep the fishermen well informed as to what is going on in other scalloping districts, what opportunities are being opened for the marketing of shellfish, how the waste products can be utilized, and how the fishery can be preserved. This report contains practically all obtainable information upon the scallop and the industry in Massachusetts at the present time. While the main facts set forth in the preceding pages about the life and habits of the scallop will remain the same, the condition of the industry will change, and in the future the descriptions of methods, implements, marketing, etc., will be of little practical value except from an historical standpoint. It is sincerely hoped that this report will attain its main object, *i.e.*, the presentation of the life history of the scallop and the needs of the industry in such a light to the fisherman that he will realize the great necessity of the preservation of the "seed" scallop for the maintenance of the fishery. At regular intervals, for instance every five years, small pamphlets containing up-to-date information concerning methods of developing the fishery, as regards implements, marketing, utilization of waste, etc., should be distributed among the scallopers.

Besides the utilization of the waste parts, the uses of which at the present time have been enumerated under the food value of the scallop,

the market can be improved in three ways: (1) To do away with the marketing of "soaked" scallops by the co-operation of the dealers and the payment of a proportional increase in price per gallon for "dry" scallops from the fisherman. (2) Co-operation between commission merchants and scallopers, which would result in better satisfaction in both goods and prices, and do away to some extent with that great bugbear, "uncertainty of returns," which is so discouraging to the fisherman and makes the fishery a lottery. (3) To increase the popular demand for scallops by wider fields through the transportation facilities and advertising.

The methods of capture will slowly improve. No suggestions can be offered here for improvements in dredges, etc., as each locality has conditions peculiar to itself. The description of the different styles of dredges in the various localities may cause innovations in certain sections which have fallen in that rut of custom so prevalent in our fishing towns. During the last few years the gasolene dredger has gradually replaced the sail, and while dredging with sail will probably remain, it will be in combination with power, as in power catboats, resulting in a partial revolution in scalloping methods.

The question of just and fair laws has been an important factor in the fishery. While in the past all laws have not met this standard, the tendency at the present time and for the future is improvement in simplicity and justice, with the sole aim of preserving the fishery, serving the consumer and protecting the fisherman.

CHAPTER VII—METHODS OF INVESTIGATION

Owing to the different classes of readers, and with a desire to present the material so that it will be intelligible to all, it has seemed best to "cull" from the main portions of the report the various methods, tables, etc., which were used in its preparation, and to incorporate them in a reference chapter, where, though accessible, they will not interfere with the continuity of the narrative. In this way the report is made more interesting to the fishermen and general public, without detracting from its scientific value. Throughout the paper constant reference is made to the contents of this chapter, for the purpose of avoiding repetition and unnecessary description.

The chapter is mainly divided into: (1) methods used in obtaining the early embryology and life history; (2) methods of conducting the growth experiments; (3) tables; (4) glossary; and (5) bibliography.

Embryological Methods.

It is hardly necessary to describe in detail the general method of investigation of the early life history of the scallop. It is sufficient to state that the usual methods of microscopic study, camera lucida

drawings, various micrometers, preparations, fixatives, etc., were employed, while the material was obtained in a variety of ways, as is hereafter described. The investigation on the life history was carried on at Monomoy Point during the summers of 1906, 1907, 1908, and 1909, and at Wellfleet in 1908. Only those methods are here described which especially apply to the scallop or show some peculiarity which rendered them of value in this investigation.

Method of measuring the Scallop Egg.—The size of the mature scallop eggs was determined with the aid of camera lucida drawings and a standard stage micrometer. This work was done with oculars 1 and 2 and objectives $\frac{3}{8}$ and $\frac{1}{6}$, Bausch and Lomb microscope, the camera lucida and stage micrometer also being obtained from the same firm. The average measurements of several batches of eggs, hatched in 1906 at Monomoy Point, just previous to fertilization, gave the long diameter as $\frac{1}{15.58}$ millimeter ($\frac{1}{396}$ of an inch) and the short diameter as $\frac{1}{16.66}$ millimeter ($\frac{1}{423}$ of an inch). These measurements do not correspond with those made by Risser (2), who found the size to be $\frac{1}{6000}$ of an inch, or about one-fifteenth as large as the measurements made in this investigation.

Method of determining the Number of Eggs produced by the Average Scallop in One Season.—How many eggs does a scallop contain at time of spawning? The answer varies with the size of the scallop, a large specimen possessing many times the number in a small one. For the purpose of determining two sizes were used, (1) small, 40 millimeters ($1\frac{3}{8}$ inches), (2) large, 68 millimeters ($2\frac{3}{4}$ inches). Taking $\frac{1}{6}$ of a millimeter ($\frac{1}{400}$ of an inch) as the average diameter of a scallop egg, the number of eggs in a cubic millimeter can be estimated as 4,096, and as there are 1,000 cubic millimeters to 1 cubic centimeter, there would be 4,096,000 eggs to 1 cubic centimeter. As it is estimated that one-fourth of the volume is taken up by egg capsules and tissue, it can be safely stated that there are at least 3,000,000 eggs to 1 cubic centimeter. The second operation consists in removing the ovaries from a number of scallops of a given size and measuring them in graduates to determine the volume of the average ovary. From this data the average number of eggs that a scallop of any size is capable of producing can be readily calculated. Twenty ovaries of scallops measuring 40.15 millimeters in size made 10 cubic centimeters, one specimen thus averaging $\frac{1}{2}$ cubic centimeter. Therefore, a 40-millimeter scallop can produce about 1,500,000 eggs in a season. The average of seven 68-millimeter scallops made the ovaries of one equal to $1\frac{3}{4}$ cubic centimeters. Therefore, a 68-millimeter ($2\frac{7}{8}$ inches) scallop may produce in a season 4,285,700 eggs.

At best this calculation is only an estimate. Exactness would be of little practical value. The errors which arise are as follows: (1) In computing the number of eggs to the cubic millimeter the eggs are

considered as spheres with intervening spaces, whereas in reality they are packed together in distorted shapes in the ovary. This perhaps offsets the second error. (2) In the second part of the computation the coils of the digestive tract, left in the ovary, are not allowed for, and with the outer covering are included in the total volume. (3) Another error arises from the fact that all the eggs may not be as large as the mature ones. (4) There is also the room taken by the egg capsules and tissues. Whether these errors offset each other, or whether the one-fourth allowance is correct, it is impossible to state. However, for all practical purposes the method and count are accurate enough.

Method of determining the Number of Spermatozoa produced by the Average Scallop in One Season.—The method of finding the number of spermatozoa in the testes of a scallop is practically the same as in computing the number of eggs in the ovaries. It takes 260 spermatozoa heads placed lengthwise to measure 1 millimeter, and 500 heads placed side by side to measure the same distance. It therefore takes 65,000,000 to make a volume of 1 cubic millimeter. By a generous allowance of 15,000,000,000 for tails and tissue there would still be left 50,000,000,000 spermatozoa to every cubic centimeter. It was found that the size of the testes and the ovaries in the same scallop was practically identical, and that the testes of a 40-millimeter and a 68-millimeter scallop measured $\frac{1}{2}$ cubic centimeter and $1\frac{3}{4}$ cubic centimeters respectively. Thus the average 40-millimeter scallop is capable of producing 25,000,000,000 and the 68-millimeter scallop 71,400,000,000 spermatozoa.

Methods of recording Spawning.—A variety of methods were employed in determining the spawning of the scallop. Chief among these were (a) general observation at the various scalloping localities of the coast; (b) microscopic examination of the eggs from the ovaries at different seasons; (c) the plankton net; (d) recording the color of the egg sac by color charts; (e) appearance of the young set in the different localities and at different years; (f) individual spawning.

(a) *General Observation.*—This method was chiefly followed in 1905 and 1906. Trips were made to the various localities, such as Edgartown, Nantucket, Buzzard's Bay, Cape Cod, and the condition of the egg sac of a large number of scallops noted both by eye and by microscopical examination. The condition of the sexual products were then classed under three heads, (1) immature, (2) spawning, (3) spawned, according as to whether the eggs had been liberated at that date. By making several trips during the summer a general idea of the duration of the spawning season and its variation in Massachusetts waters was obtained. This method, though naturally inaccurate in the minor details, nevertheless proved extremely useful.

(b) *Microscopical Examination.*— This method was used to more or less extent with (a), and was only of additional value in following the development of the immature eggs previous to the spawning season, showing at what period other investigations should be started. The eggs and sperm were removed from the ovary, placed on a slide and their size and appearance recorded, the sperm being classed as (1) active or (2) inactive.

(c) *The Plankton Net.*— A small net of silk bolting cloth No. 11, with a diameter of 12 inches, and slightly tapering for 24 inches to a rounded bottom, was used for this work. By towing the net through the water the veliger larvæ, which are abundant during spawning season in the water, could be captured. This is an important method of recording the spawning, as the presence of scallop veligers from two to four days old is proof that the spawning season is under way. By making daily tows under the same conditions and for a definite distance, it was possible to count the number of larvæ in the water each day, and thus determine the conditions influencing the spawning season. Although this method has been of greater value in the work on the other shellfish, as the same method is applicable to lamelli-branches in general, a description is here given.

The plankton net, as shown in Fig. 72, is attached in the form of a bag to a copper ring, to which the tow line is fastened in the same manner as a kite string. The outfit is trailed from the stern of a dory or rowboat for a definite distance at a slow, uniform rate, so that no outward current will sweep away the larvæ from the mouth of the net, which acts as a sieve to collect all microscopic organisms too large to pass through the meshes.

When the proper distance is covered, the net is taken from the water and the contents washed into a small pail containing from 4 to 5 inches of clear sea water. The lamellibranch and gasteropod larvæ are now separated from the rest of the tow contents by giving the water a swift circular movement around the edge of the pail with a small stick. The action of the water forces the larvæ to settle to the bottom at the center of the pail, where they can be readily transferred by a pipette to a watch glass for study.

A convenient means of analyzing the towing similar to the Sedgwick-Rafter method of a diatom counting was devised. The larval contents of the towing was spread evenly throughout a cell 50 by 20 by 1 millimeters, covering an area of 1,000 square millimeters, or a cubic volume of 1 cubic centimeter, and ten counts ($\frac{1}{100}$ of the total area), each covering an area of 1 square millimeter as measured with a square ocular micrometer, were made from different parts of the cell to get a representative average. The approximate number of larvæ for each species of shellfish was obtained by multiplying the sum of these counts by 100.

(d) *The Color Chart.*—The color of the ovaries of a scallop is an excellent test of their maturity, as when distended with ripe eggs they generally have a rich orange hue. Before and during the spawning season all grades of color from a flesh pink to a deep orange can be found. While doubtless there is considerable variation in the color at maturity, the general average is sufficiently constant to warrant using it as a basis for recording the spawning season. By the use of Prang's color chart a record of the spawning of scallops in the different sections was made. At Monomoy Point, by examining the color of the ovaries without injuring the scallop (the valves being merely held wide apart), the same lots of scallops were followed during the entire summer, and the color changes indicative of the spawning season charted at weekly intervals, according to the standard grades of color in the chart.

(e) *Appearance of Set.*—By observations of the appearance of the set in different localities, and having already a knowledge of the age of the scallop at this period, the date of spawning could be correctly estimated. The sets, taken on the spat boxes at Monomoy Point, were carefully recorded for four years, and in other localities when opportunity was given.

(f) *Artificial Spawning.*—In order to obtain accurate data as to the spawning of individual scallops the following method was employed: a large glass aquarium containing fresh sea water was placed on the warm sand in the sunlight. Small glass jars, each containing enough sea water to cover a scallop, were placed near the aquarium. The scallops were gently scrubbed with a brush, rinsed in a pail of clean salt water, and placed one in each of the small jars, under which dark paper was placed to facilitate detection of spawn. The usual number under observation at any one time was 16, which proved the most convenient number to watch. In order to prevent injury to the developing eggs by contact with metal the temperature was taken from a separate jar containing the same amount of water. The temperature of the water was taken at the time the scallops were put in and at the discharge of the first lot of spawn. At each spawning the contents of the small jar was transferred to a bottle labeled with the number of the scallop, number and time of discharge, and examined microscopically to determine whether eggs, spermatozoa or both were liberated. The animal and dish were rinsed in the pail, fresh water of the same temperature was taken from the aquarium, and the scallop returned to its former position.

Artificial Fertilization.—Two methods of artificial fertilization have proved most satisfactory in the study of shellfish larva: (1) removal of the sexual products by cutting; (2) forcing the spawning, although the former is not as successful with the scallop as with the oyster, as there are certain drawbacks, such as the crushing of the eggs,

abnormal development, non-fecundation of the numerous immature eggs, and sacrificing the parent. The other method (forced spawning) is accomplished by transferring the scallops from cool to warmer water, which causes the ripe eggs to be extruded in a more natural manner. Spawn could be obtained at any time during the season if the temperature was satisfactory, and the same scallops could be used over and over.

In raising the larvæ for laboratory study the aquaria should be kept clean, a relatively large amount of water for a few larvæ should be allowed, as crowding results in death, and the decomposing eggs, if not separated by siphoning off the surrounding embryos, soon cause the death of all. With every precaution the death rate is very high, owing to the débris, parasitic protozoa, bacteria, etc., which collect in the water, but there is good reason to believe that by careful experiment scallops can be raised in numbers in the laboratory, although during this investigation only a few were successfully carried to the post-embryonic stage.

Artificial Propagation.—The object of artificial propagation is the prevention of the great "infant mortality," as under natural conditions but $\frac{1}{50,000}$ of 1 per cent. of the number of eggs develop into mature scallops. Artificial fertilization and the protection of the young embryos during the first few days of life would to a large extent do away with this great loss; but the practical difficulties in successfully rearing the larvæ over this period are such as to make the undertaking problematic. At the present time liberation of the eggs immediately after artificial fertilization seems to be of most benefit to the fishery.

The Rate of Growth.

Methods of measuring the Scallops.—Three measurements were made of each scallop (Fig. 65): (1) *height*, along the dorso-ventral axis, or from the hinge to the opposite edge of the shell; (2) *width*, along the antero-posterior axis, or from the left to right edge of the shell; (3) *thickness*, along the lateral axis, or the depth through the valves.

The growth of any mollusk can only be accurately stated by determining the gain in volume. As it was obviously impossible to obtain the water displacement of the scallop with its loose shell, the following method of calculating the volume was devised: the three dimensions of the scallop were multiplied together and the result called the *cubic volume*, equivalent to the volume of a solid rectangular prism of those dimensions, in which the scallop is theoretically enclosed. Thus the following proportion can be established: scallop A of cubic volume 1,000 is to scallop B of cubic volume 5,000 as 1,000 is to 5,000 (A:B::1,000:5,000). Thus scallop B is five times, or 500 per cent., larger than scallop A, and the relative per cent. of increase is ob-

tained with the same results as if the water displacement had been taken. By taking several hundred measurements of width and thickness for scallops of the same height a table has been formulated, giving the average width, thickness and cubic volume for every sized scallop. Thus having given the height of any scallop, the cubic volume can be found and any gain in length transformed into gain in volume.

Measuring Instrument. — For speed, exactness and uniformity in measuring large numbers of scallops it was necessary to have a suitable measuring implement. (Fig. 105.) The instrument, designed for this work by the writer, consists of an inverted triangle, formed by two strips of metal welded together at the apex of the triangle, and joined at the base by a short cross piece. The whole instrument is made of brass except the braised joint, and can be made as light as desired, although there is danger of a heavy blow rendering a light measurer inaccurate. Several sizes were used in the work, the most convenient having a base measuring 3 inches. On the sides of the triangle the scale is marked in millimeters. The measure is scaled in a simple manner by taking across the broad end a certain width in millimeters, measuring the length of the instrument, and subdividing it into a certain number of equal parts, each corresponding to 1 millimeter. This gives easier and more accurate readings as it is possible to read to $\frac{1}{2}$ of a millimeter with the same accuracy as to 1 millimeter on an ordinary rule, each division on the triangle having actual measurement of nearly 5 millimeters. When measuring, the triangle is held with the base away from the body, and the object is brought down the narrowing sides until it strikes, at which point the measurement is read.

The value of the instrument arises from the rapidity with which measurements can be made, as only one movement is required to record the length of an object. Measurements could be made nearly twice as fast as by using calipers, where two movements are required. A proficient person can measure as high as 400 scallops per hour, three measurements being taken for each scallop, or a total of 1,200. The ordinary person can measure about 300 in the same time, or 5 scallops per minute. This instrument can be used for measuring a variety of objects, and students of variation, where rough measurements are alone required, will find it of great convenience.

Growth Experiments. — The growth experiments were carried on in two ways: (1) by measurements at definite periods of the various sets in the different waters of the Commonwealth; (2) by growth in pens at Monomoy Point, Monument Beach, Marion and Chatham.

In the first case the work chiefly consisted of measurements, taken as described above, of a large number of scallops at each time, so as to obtain a correct average. During the first year three measurements of each scallop were made, until sufficient material was at hand to

formulate Table D. Afterwards only one measurement, the height, was taken, as the gain in volume for any locality could be determined from the table. The growth line proved of great assistance, as the increase from May 1 at any date could be determined by making two measurements, (1) the height, and (2) the growth line.

Tagged Scallops.—A method of recording the growth of individual scallops as well as obtaining data upon their migratory habits was obtained by "tagging" each specimen. A small hole was punched through the "ear" close to the hinge line, and a numbered copper tag was attached by a fine wire, as in Fig. 66. The scallops were then liberated in the Powder Hole, after their measurements were taken. Whenever found, the number and size were recorded, thus obtaining the exact growth of the individual specimens. The tag apparently did not interfere with the growth or movements of the animals.

Another method of identification was used in the pens. The scallops were notched with a file across one valve, the number of notches giving the class of the scallop when more than one size were confined in the pen.

The Pens.—Most of the growth experiments were conducted in pens (Fig. 80), as the activity of the scallop rendered confinement necessary. In this way, under what might be termed artificial conditions, the rate of growth of *Pecten irradians* was obtained in several localities. The pens were of two kinds: (1) of 1¼-inch wire chicken netting; (2) of old seines. They were constructed by driving in the soil posts of 2 by 3 inch joist, at sufficient intervals to hold the netting firmly in position. When wire netting was used little difficulty was experienced in making the bottoms of the pens tight to prevent the escape of the scallops, as the netting set firmly on the soil, which had previously been leveled. When seines were used the bottom was secured either by baseboards or by fastening the netting by long wooden pegs, an uncertain method at best. The pens were made either of a sufficient height to rise above the average tide, which was possible at Chatham and Monomoy Point, where there is a comparatively small rise and fall of the tide, or were fitted with netting tops when the tide proved high, as at Marion and Monument Beach. The pens, which ranged from 40 to 400 square feet in size, were situated in water from 1 to 2½ feet in depth at low tide, and under a variety of conditions as regards current, soil, eel grass and tide.

Wire Cages.—Scallops were suspended in wire cages (Fig. 71) from a raft in the Powder Hole, Monomoy Point, in order to obtain the rate of growth, especially of the young "seed," too small to confine in pens. The baskets consisted of a wooden framework, 2½ feet long, 1½ feet wide, 1 foot deep, covered by netting with ¼ to 1¼ inch mesh. Smaller cages were used for the young scallop with galvanized mosquito netting. The objection to the use of a small mesh is due to the

restriction of the water circulation by the clogging of the fine meshes by plant growth. This was avoided as much as possible in the growth experiments by frequently cleaning the cages, and transferring the small scallops as soon as their size permitted to the larger cages. In spite of this care the growth of the "seed" inside the cages proved less than those attached outside. Old scallops, as well as young, were confined in the baskets for growth records.

The Biological Raft.—The raft (Fig. 79) from which the wire baskets were suspended proved particularly useful in the study of the post-embryonic life history of the scallop, which "set" in numbers on the boxes, wire cages and ropes, where specimens could be obtained in all stages of development for laboratory examination. From the raft at various depths were suspended wire cages and boxes, in which growth experiments upon the quahaug, clam and scallop were conducted. The raft, 20 feet long by 10 feet wide, was made of two 4 by 6 inch beams, 20 feet long, which were held in place by cross beams, 3 by 4 inches in size. On the framework was a floor, except for a large central "well." Four trapdoors led to smaller "wells" on each side. The raft was buoyed by six oil barrels, two on each end and two on the sides, and was moored in the Powder Hole in 20 feet of water. The scheme of box spat collecting from a raft is recommended to biological students, as the young of many worms, crustaceans, mollusks and other marine forms are caught easily in sand boxes.

A. Life Table.

STAGE.	Age.	Shape.	Size (Inches).	Movement.
Egg, . . .	-	Spherical, .	1/400, . .	None.
Two cells, . . .	46 minutes, .	-	1/400, . .	None.
Four cells, . . .	67 minutes, .	-	1/400, . .	None.
Eight cells, . . .	81 minutes, .	-	1/400, . .	None.
Sixteen cells, . . .	100 minutes, .	-	1/400, . .	None.
Blastula, . . .	9 hours, . .	Mulberry, .	1/400, . .	None.
Ciliated gastrula,	10 hours, . .	-	1/400, . .	Cilia.
Trochosphere, . .	12 hours, . .	Elongate, .	1/400, . .	Cilia and flagellum.
Early veliger, . .	40 hours, . .	Flat hinge, .	1/275, . .	Velum.
Late veliger, . .	5 days, . . .	Umbones, .	1/152, . .	Foot.
Dissoconch, . . .	8 days, . . .	Scallop, . .	1/152 to 1/20, .	Foot.
Plicated,	20 days, . . .	Scallop, . .	1/20 to 1/6, . .	Foot and valves.
Youth,	Up to 1 year, .	Scallop, . .	1/6 to 1/6, . .	Valves.
Adult,	Over 1 year, .	Scallop, . .	1/6 to 2 1/4, .	Valves.

C. Stages of Development.

In order to give a brief consecutive narrative to the life history of the scallop it was found necessary to confine the detailed descriptions of the period following the time of "set" to the reference portion of the report. For this purpose the life of the young scallop during the dissoconch and the plicated stages has been arbitrarily divided into eight periods. The chief characteristics of each of these periods are described in tabulated form and refer to the drawings of the early stages. In making the divisions the shell has been taken as the standard, and each stage is differentiated by some change in formation.

THE SCALLOP FISHERY

	1.	2.	3.	4.	5.	6.	7.	8.
Figures,	19, 20.	21, 22, 23.	24.	25, 26, 27, 28.	29, 30.	31, 32.	33, 34.	35, 36, 37.
Character,	No strip across byssal notch.	1 strip across byssal notch.	2 to 3 strips across byssal notch.	No teeth on byssal notch.	1 tooth on byssal notch.	2 teeth on byssal notch.	Plications begin.	Plicated stage.
Age,	1 day after set.	2 days after set.	3 to 4 days after set.	6 to 8 days after set.	9 to 10 days after set.	13 to 14 days after set.	16 to 18 days after set.	20 to 22 days after set.
Size, . . . . .	.2 by .246 of a millimeter.	.24 by .29 of a millimeter.	.38 by .4 of a millimeter.	.63 by .75 of a millimeter.	.98 by 1.1 millimeters.	1 by 1.15 millimeters.	1.26 by 1.25 millimeters.	1.4 by 1.4 millimeters.
Lines of growth,	None.	1.	2 to 3.	5 to 7.	9 to 12.	10 to 13.	11 to 14.	11 to 14.
Hinge line,	Straight (10 pairs teeth); length, 186.	Straight; length, 166.	Slightly curved.	Straight.	Straight.	Straight.	Straight.	Straight.
Left valve,	More convex than right.	More convex than right.	More convex than right.	More convex than right.	More convex than right.	More convex than right.	More convex than right.	Same curvature as right.
Right valve,	Prismatic structure.	Prismatic structure.	Prismatic structure.	Prismatic structure.	Prismatic structure.	Prismatic structure.	Plicated growth not prismatic.	Plicated growth not prismatic.
Byssal notch,	Just formed.	1 strip.	2-3 stripes.	Present.	Present.	Present.	Present.	Present.
Byssal groove,	None.	None.	None.	None.	None.	None.	None.	None.
Byssal teeth,	None.	None.	None.	None.	None.	None.	None.	None.
Color,	None.	None.	None.	None.	None.	None.	None.	None.
Mantle,	Simple.	Simple.	Simple.	Complex.	Complex.	Guard flap.	Guard flap.	Guard flap.
Tentacles,	None.	None.	None.	9 primary.	Primary and secondary.	Primary, secondary, tertiary.	Primary, secondary, tertiary.	Primary, secondary, tertiary.
Eyes,	None.	None.	None.	Beginning.	Present.	Present.	Present.	Present.
Pseudo-siphon,	None.	None.	None.	None.	19 inner, 7 outer.	23 inner, 10 outer.	Numerous inner, 30 outer.	Numerous inner, 25 outer.
Gills,	4 filaments.	4 large, 3 small filaments.	6 large, 3 small filaments.	None.	None.	None.	None.	None.
Foot,	Ciliated tip.	Ciliated tip.	Ciliated tip.	Ciliated tip.	Ciliated tip.	Ciliated tip.	Ciliated tip.	Ciliated tip.
Byssal gland,	Present.	Present.	Present.	Present.	Present.	Present.	Present.	Present.
Otocyst,	Present.	Present.	Present.	Present.	Present.	Present.	Present.	Present.
Blood system,	No heart beat seen.	No heart beat seen.	No heart beat seen.	Heart conspicuous.	Heart conspicuous.	Heart conspicuous.	Heart conspicuous.	Heart conspicuous.
Adductor muscle,	Posterior.	Posterior.	Posterior.	Posterior.	Posterior.	Posterior.	Posterior.	Posterior.
Digestive tract,	Simple coil of intestine.	Simple coil of intestine.	Simple coil of intestine.	Coiled.	Coiled.	Coiled.	Several coils.	Several coils.

NOTE. — Rate of growth from this time on varies with the conditions under which the scallop is placed, i.e., its environment.

D. Comparative Table of Size and Volume.

In the following table of scallops from 1 to 80 millimeters for each size (height), the average width and thickness are taken from the measurements of many specimens. *Height* is the measurement along the dorso-ventral axis, or from the hinge to the opposite edge of the shell; *width*, along antero-posterior axis, or from the left to right edge of the shell; *thickness*, along the lateral axis, or the depth through the valves. The cubic volume is expressed in cubic millimeters as *height* times *width* times *thickness*. For each size the number per quart is given in the fifth column. This table proved very useful in determining the gain in volume in the planted beds and in the localities under observation, as by merely having the original size and increase in *height*, the gain in volume could be readily calculated.

Height.	Width.	Thickness.	Cubic Volume.	Number per Quart.	Height.	Width.	Thickness.	Cubic Volume.	Number per Quart.
1	1.0	.2	.2	7,927,275.00	25	25.0	8.9	5,563.0	285.00
2	3.8	.5	1.8	880,820.00	26	26.0	9.3	6,287.0	252.20
3	2.7	.8	6.5	248,960.00	27	27.0	9.7	7,071.0	224.20
4	2.6	1.1	11.4	188,596.00	28	28.1	10.1	7,947.0	199.50
5	4.5	1.5	33.8	45,898.00	29	29.2	10.5	8,891.0	178.30
6	5.4	1.8	58.3	27,195.00	30	30.3	11.0	9,999.0	158.30
7	6.3	2.1	93.6	17,123.00	31	31.4	11.5	11,194.0	141.60
8	7.3	2.5	146.0	10,859.00	32	32.5	11.9	12,376.0	128.10
9	8.3	2.8	209.0	7,583.00	33	33.6	12.4	13,749.0	115.30
10	9.3	3.1	288.0	5,506.00	34	34.7	12.9	15,219.0	104.20
11	10.2	3.4	382.0	4,150.00	35	35.8	13.3	16,665.0	95.00
12	11.2	3.8	511.0	3,103.00	36	36.9	13.7	18,199.0	87.10
13	12.2	4.1	650.0	2,439.00	37	38.0	14.1	19,825.0	80.00
14	13.2	4.4	813.0	1,960.00	38	39.2	14.5	21,599.0	73.40
15	14.2	4.8	1,022.0	1,551.00	39	40.4	15.0	23,634.0	67.10
16	15.3	5.2	1,278.0	1,245.00	40	41.6	15.5	25,792.0	61.40
17	16.4	5.6	1,561.0	1,016.00	41	42.8	16.0	28,077.0	56.50
18	17.5	6.0	1,890.0	838.80	42	43.9	16.5	30,423.0	52.10
19	18.6	6.4	2,262.0	700.90	43	45.0	17.0	32,895.0	48.20
20	19.6	6.8	2,666.0	595.60	44	46.2	17.5	35,574.0	44.60
21	20.7	7.2	3,130.0	506.40	45	47.4	18.0	38,394.0	41.30
22	21.8	7.6	3,645.0	434.90	46	48.6	18.5	41,359.0	38.50
23	22.9	8.0	4,214.0	376.20	47	49.8	19.0	44,471.0	35.65
24	23.9	8.5	4,876.0	325.20	48	50.9	19.5	47,642.0	33.30

Height.	Width.	Thickness.	Cubic Volume.	Number per Quart.	Height.	Width.	Thickness.	Cubic Volume.	Number per Quart.
49	52.1	20.0	51,058.0	31.00	65	70.3	29.6	125,257.0	11.73
50	53.2	20.5	54,539.0	29.10	66	71.4	30.2	142,314.0	11.14
51	54.4	21.1	58,540.0	27.20	67	72.6	30.8	149,817.0	10.58
52	55.5	21.7	62,626.0	25.39	68	73.8	31.5	158,090.0	10.08
53	56.7	22.3	67,014.0	23.65	69	75.0	32.2	166,635.0	9.51
54	57.9	22.9	71,599.0	22.15	70	76.2	32.9	175,489.0	9.03
55	59.1	23.5	76,387.0	20.75	71	77.4	33.7	185,195.0	8.56
56	60.3	24.1	81,381.0	19.50	72	78.6	34.5	195,242.0	8.12
57	61.4	24.7	86,445.0	18.24	73	79.8	35.2	205,054.0	7.73
58	62.5	25.3	91,713.0	17.30	74	81.0	35.9	215,184.0	7.37
59	63.6	25.9	97,187.0	16.30	75	82.1	36.6	225,364.0	7.03
60	64.7	26.5	102,873.0	15.40	76	83.2	37.3	235,855.0	6.72
61	65.8	27.1	108,774.0	14.56	77	84.4	38.1	247,804.0	6.40
62	67.0	27.7	115,066.0	13.78	78	85.6	38.9	259,728.0	6.14
63	68.1	28.3	121,415.0	13.06	79	86.8	39.7	272,231.0	5.82
64	69.2	29.0	128,485.0	12.34	80	88.0	40.3	285,120.0	5.56

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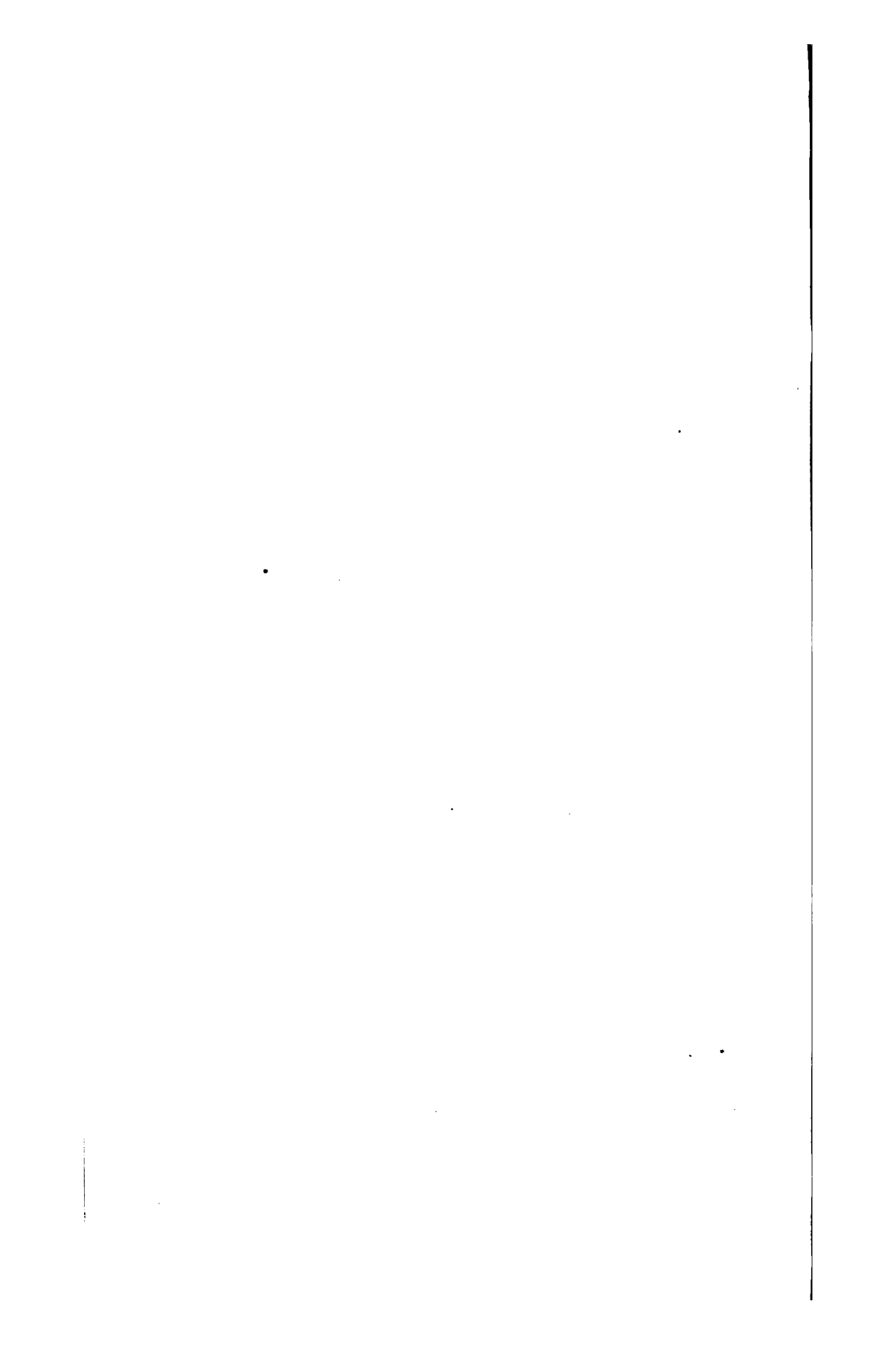
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GLOSSARY.

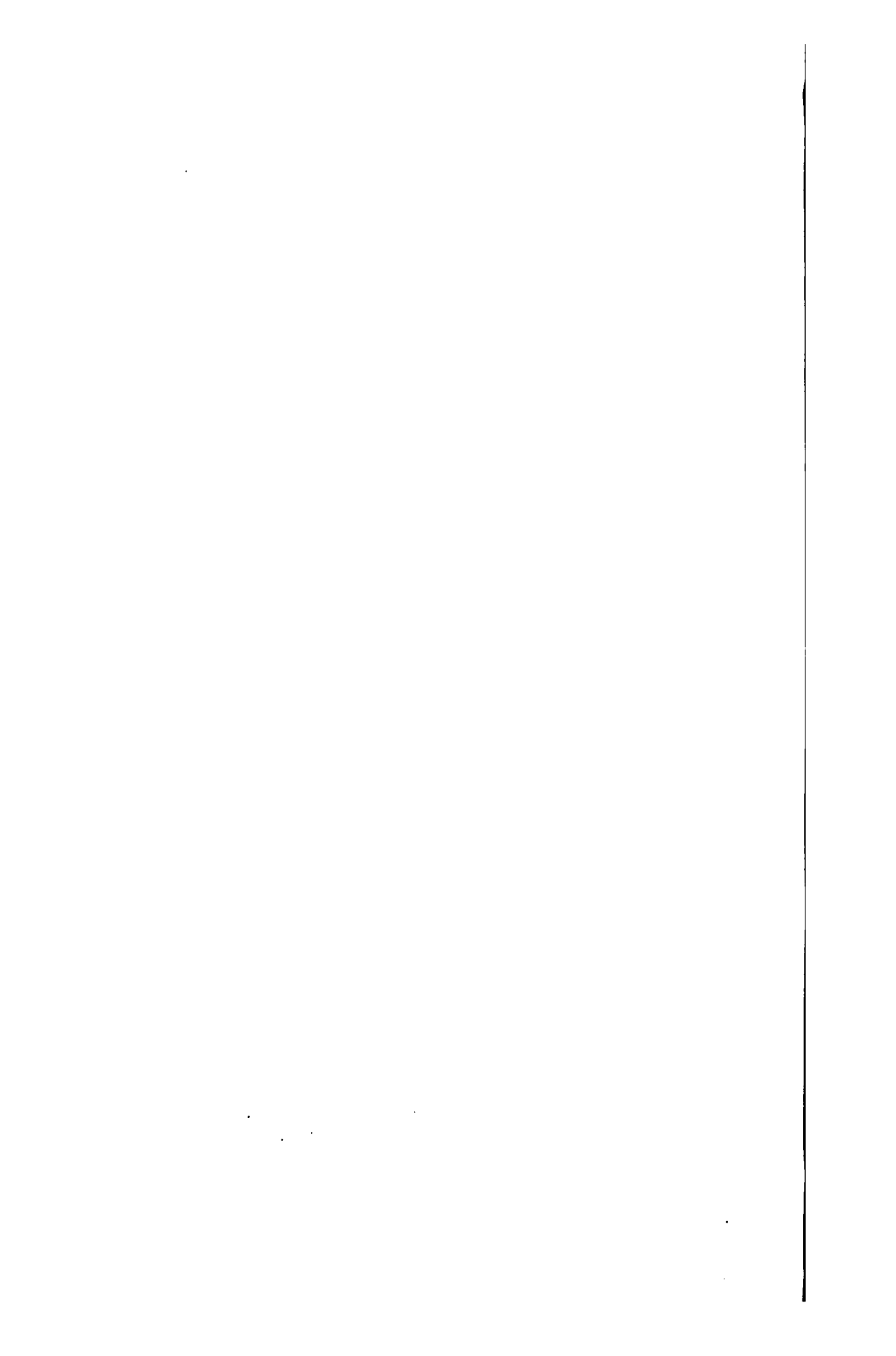
Adductor muscle,	. . .	Muscle which draws the two valves (shells) together.
Anterior,	. . .	Front.
Archenteron,	. . .	Primitive or original digestive tract.
Asymmetrical,	. . .	Not symmetrical.
Auricle,	. . .	A chamber of the heart.
Bathymetrical,	. . .	Relating to the depth in the sea.
Blastopore,	. . .	The opening into the archenteron.
Blastula,	. . .	An early stage in the development of the embryo, in which the outer cells form a definite layer.
Byssus,	. . .	Thread-like fibers secreted by the foot for attachment.
Cell,	. . .	The unit structure of life.
Cilia,	. . .	Filamentous protoplasmic processes.
Cleavage,	. . .	Natural division of the egg cells.
Cloacal chamber,	. . .	Space into which waste material is discharged before passing out the excurrent siphon.
Crystalline style,	. . .	A transparent gelatinous rod which lies along the upper part of the intestine.
Cytoplasm,	. . .	That part of the protoplasm outside of the nucleus.
Diatoms,	. . .	Microscopic plants, which constitute the food of the shellfish.
Dimyarian,	. . .	Having two adductor muscles, as the quahaug.
Dissoconch,	. . .	Literally, two shelled; babyhood shell with no plications.
Dorsal,	. . .	Referring to the back of the animal but not necessarily the upper side.
Ectoderm,	. . .	The external outer layer of cells.
Egg,	. . .	The female germ cell—ovum.
Egg capsule,	. . .	Case in which the egg is inclosed.
Embryo,	. . .	The first rudiments of an organism.
Endoderm,	. . .	The inner cell layer.
Equilateral,	. . .	Having all sides equal.
Equivalentular,	. . .	When two valves are alike in size and shape.
Exoskeleton,	. . .	Outside framework or support, differing from a true skeleton or endoskeleton, which is inside the body.

Fecundation, . . .	Impregnation of the ovum by the spermatozoön.
Fertilization, . . .	Fecundation.
Flagellum, . . .	A long, whip-like cilium.
Follicle, . . .	A small cavity.
Formative cells, . . .	Cells which form the animal in contrast with cells which furnish them with food.
Ganglion, . . .	A mass of grey nervous substance, which serves as a center of nervous influence.
Gastrula, . . .	An embryonic stage which has the form of a double-walled sac with an opening leading into a cavity, the archenteron.
Genus, . . .	Group of species.
Geotropic, . . .	Showing a disposition to incline toward the earth.
Germ cell, . . .	That which is to develop a new individual.
Gills, . . .	Respiratory organs in water, comparable to the lungs in air.
Gland, . . .	A cell or collection of cells having the power of secreting.
Hermaphrodite, . . .	An animal having both male and female generative organs.
Invagination, . . .	One of the methods by which the various germinal layers of the ovum are differentiated.
Lamella, . . .	A thin plate or scale.
Lamellibranchiata, . . .	Animals of the mollusk family that have the gills arranged in leaf-like layers.
Larva, . . .	The animal during its development until it reaches adult size.
Lumen, . . .	An opening, space or cavity.
Macromere, . . .	One of the larger cells, resulting from segmentation of the egg.
Micromere, . . .	One of the smaller cells, resulting from segmentation of the egg.
Mantle, . . .	The fleshy, membranous covering, lining inside of the shell.
Mantle cavity, . . .	The space between the mantles.
Maturation, . . .	The process of ripening or coming to maturity of the egg.
Migration, . . .	Act of traveling from one region to another.
Monomyarian, . . .	Having one adductor muscle, as with the scallop and oyster.
Nacreous structure, . . .	Pearly layer of shell, generally on the inside.
Nucleoli, . . .	Smaller divisions or parts of the nucleus.
Nucleus, . . .	Germinative spot.
Otocysts, . . .	Organs of equilibration.
Ovary, . . .	The organ of a female in which the eggs are formed.
Ovum, . . .	The egg.
Pecten, . . .	Scientific name of the scallop.
Pericardium, . . .	Membrane inclosing the heart.
Posterior, . . .	Opposite to anterior.

- Prismatic structure, . . . Shell made up of prisms.
- Prodissoconch, . . . Small embryonic shell of a mollusk.
- Protandric, . . . Having male sexual organs while young, and female organs later in life.
- Protoplasm, . . . Cell contents — life substance.
- “Seed” scallop, . . . A scallop less than one year old.
- Set, . . . Attaching of scallop by byssus.
- Spawning, . . . To set free the eggs or spermatozoa.
- Spermatozoön, . . . The male sex cell.
- Tentacle, . . . A more or less elongated process, usually an organ of sense or motion.
- Testis, . . . The male gland which produces the spermatozoa.
- Trochosphere, . . . Stage in embryonic development, in which the embryo is spherical and rotates rapidly.
- Umbo, . . . The beak or “shoulder” of the bivalve shell.
- Valves, . . . Two valves, the right and left, compose the shell of a lamellibranch mollusk.
- Veliger, . . . Stage in embryonic development in which velum is used as an organ of locomotion.
- Velum, . . . A circular pad covered with cilia and used as an organ of locomotion in the early embryonic stages.
- Ventral surface, . . . The side opposite the dorsal surface.
- Ventricle, . . . A chamber of the heart.
- Visceral mass, . . . That part of body containing digestive, generative and part of circulatory and nervous systems.



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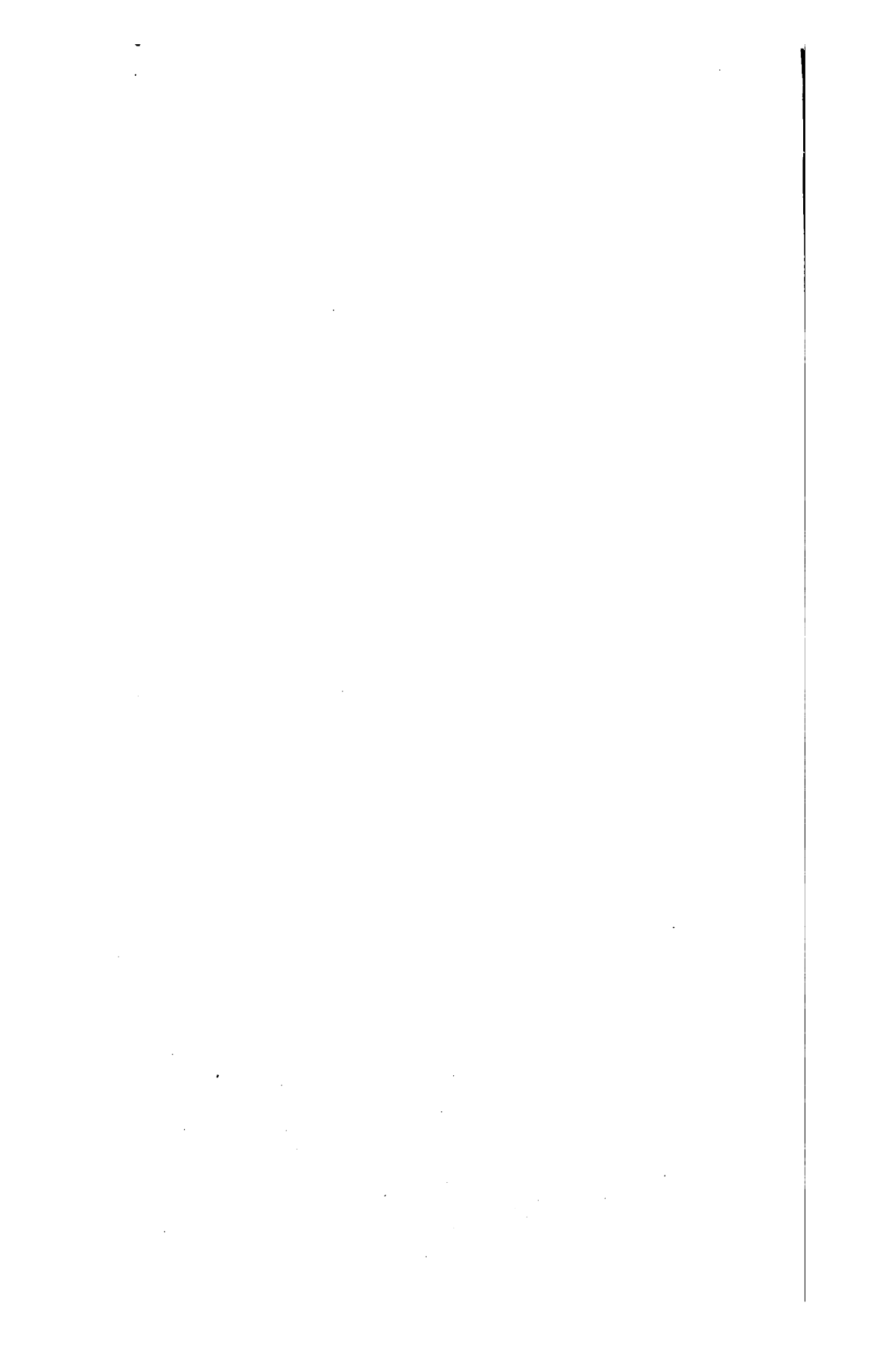
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ABBREVIATIONS.

a. — anus.
aa. — anterior adductor muscle.
b. — byssus.
bg. — byssal gland.
bgr. — byssal groove.
bn. — byssal notch.
d. — dissoconch.
di. — distal end.
er. — "ear."
f. — foot.
fc. — foot cleft.
fg. — foot groove.
fl. — flagellum.
fr. — foot retractor muscle.
g. — gills.
h. — hinge line.
ht. — heart.
i. — intestine.
ig. — inner gills.
l. — liver.
lp. — labial palps.
m. — mantle.

mf. — mantle flap.
mt. — mouth.
o. — otocyst.
og. — outer gills.
ov. — ovary.
pa. — posterior adductor muscle.
pc. — polar cells.
pd. — prodissoconch.
pl. — plicated growth.
pm. — primitive mouth.
pr. — proximal end.
ps. — pseudo-siphon.
r. — retractors of velum.
s. — stomach.
sg. — shell gland.
t. — tentacles.
te. — teeth.
ts. — testis.
v. — velum.
vm. — visceral mass.
yl. — yolk lobe.

- Fig. 1.** — Mature egg ready for union with male cell. Magnified 600 diameters.
- Fig. 2.** — Spermatozoa (male cells). Note length of tail and variation in shape of head. The spermatozoön on the left is the most common form. No attempts were made to study the minute anatomy. Magnified 600 diameters.
- Fig. 3.** — Compressed egg. Shape due to pressure of eggs within ovary. Shortly after extrusion it becomes spherical. Magnified 600 diameters.
- Fig. 4.** — Egg enclosed in membranous case. Magnified 600 diameters.
- Fig. 5.** — Egg, forty-three minutes after fecundation, showing the yolk lobe (yl) and two polar cells (pc). The formation of the yolk lobe has given to the egg a pear-shaped appearance. Magnified 600 diameters.
- Fig. 6.** — Ring of spermatozoa with radiating tails held away from the egg by a membrane. The entire surface of the membrane is covered by the spermatozoa, but only those in one plane are here shown. Magnified 600 diameters.
- Fig. 7.** — Two-celled stage, forty-six minutes after fecundation, showing unequal division. The larger cell contains the yolk lobe (yl). Magnified 600 diameters.
- Fig. 8.** — Four-celled stage, sixty-seven minutes after fecundation. Magnified 600 diameters.

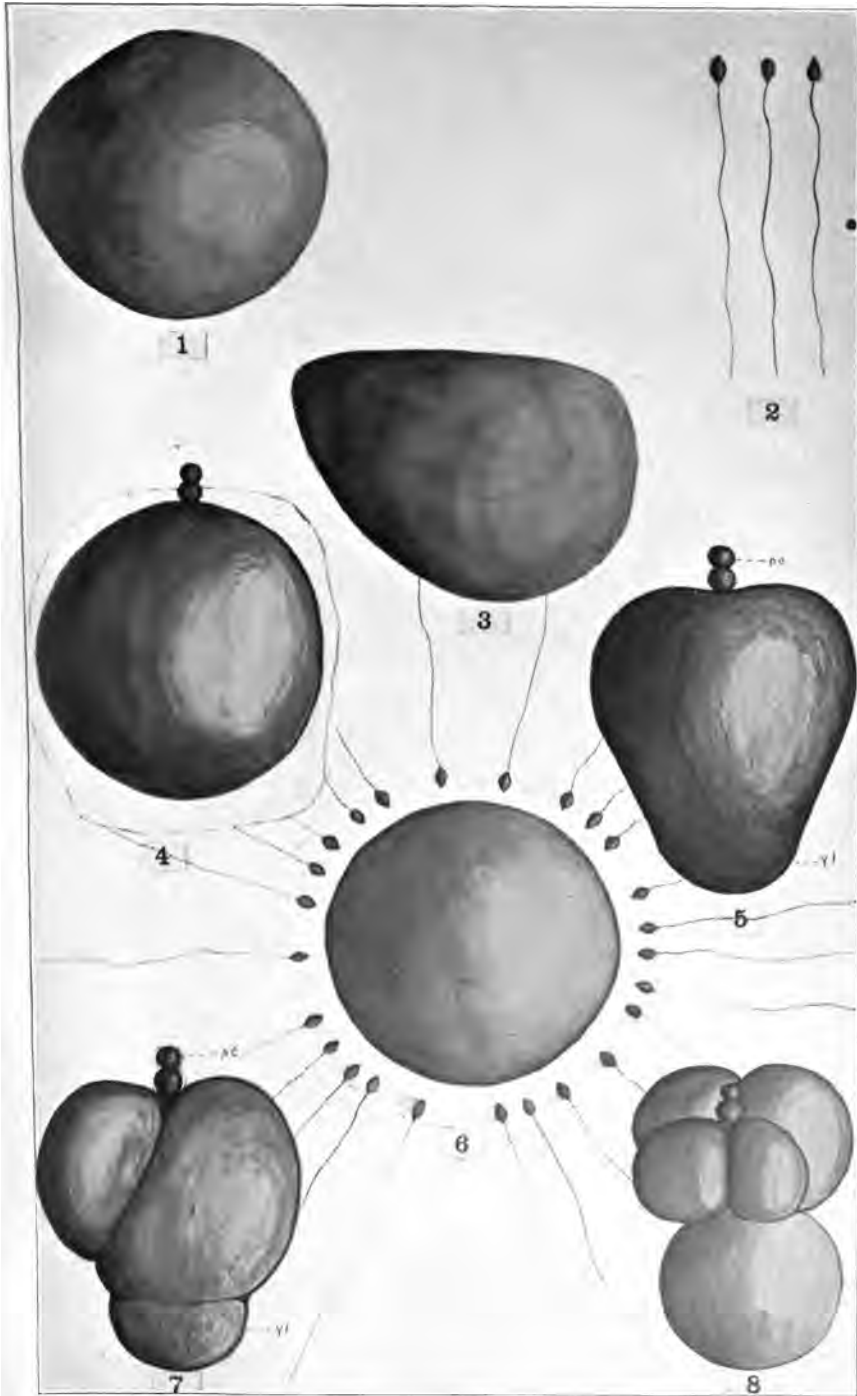


Fig. 9. — Eight-celled stage, side view, eighty-one minutes after fecundation. Magnified 600 diameters.

Fig. 10. — Sixteen-celled stage, viewed from below, one hundred minutes after fecundation. Note large yolk cell. Magnified 600 diameters.

Fig. 11. — Blastula stage, viewed from below, about nine hours after fecundation. The original egg has developed, by repeated divisions, into a mass of cells, giving it a mulberry-like appearance. The large yolk cell has divided into four macromeres, the rest of the cells constituting the micromeres. Magnified 600 diameters.

Fig. 12. — Ciliated gastrula, ten hours after fecundation. The embryo can now swim through the water by means of the hair-like cilia. The larger cells have become invaginated. Magnified 600 diameters.

Fig. 13. — Optical section of ciliated gastrula. Magnified 600 diameters.

Fig. 14. — Trochosphere stage, twelve to fourteen hours after fecundation. The body has elongated and the cilia are now confined to the front end. Note the long feeler or flagellum, which serves to guide the animal. The opening of the primitive mouth can be seen on the lower side, while above is a slight indentation corresponding to the beginning of the shell gland. Magnified 600 diameters.

Fig. 15. — Formation of the shell, which arises at two symmetrical points of calcification, right and left of the median line, and gradually envelops the animal. Magnified 600 diameters.

Fig. 16. — Early veliger larva, viewed from the side. The animal arrives at this stage from seventeen to forty hours after fertilization, according to external conditions. The duration of this stage is probably from five to six days, during which the animal leads a free swimming life. Magnified 600 diameters.



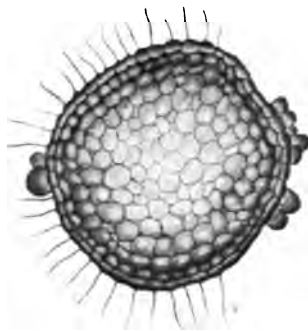
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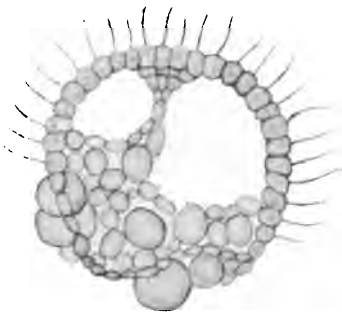
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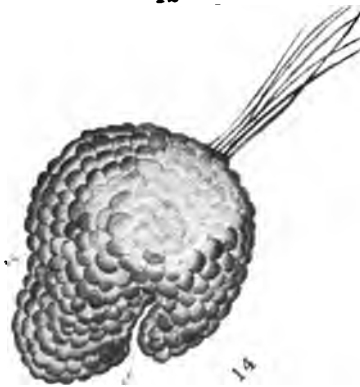
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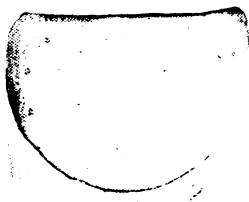
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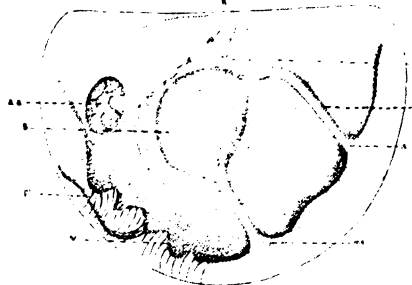
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Fig. 17. — Early veliger swimming with velum extended. Viewed from side. Magnified 150 diameters.

Fig. 18. — Late veliger or prodissoconch. Note change in form of shell, as compared with Fig. 17. This stage marks the end of the embryonic period, as the scallop now forsakes its free swimming life and attaches itself to objects by means of its byssus or "anchor strands." Magnified 150 diameters.

Figs. 19 to 32, inclusive, cover the next distinct stage of development. This form is called "dissoconch," *i.e.*, double shell.

Fig. 19. — Dissoconch Phase 1. Early dissoconch growth after scallop has "set." View of right or lower valve. Note beginning of byssal or foot notch (bn). Scallop is now capable of byssal attachment. Right valve is slightly smaller than left. Magnified 150 diameters.

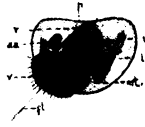
Fig. 20. — View of left valve of same scallop as in Fig. 19. Anatomy shown through transparent shell. Note increased number of gill filaments. Magnified 150 diameters.

Fig. 21. — Dissoconch Phase 2. About two days after "set." View of transparent right valve through which the organs are seen. The right valve is less convex than the left, for aid in crawling. The heart (ht) is observed for the first time during this stage. Note the slower growth of the byssal or foot notch, which is one period behind the growth of the rest of the shell. Note also the increase in the number of gill filaments. Magnified 150 diameters.

Fig. 22. — Internal view of shell of scallop of same age as in Fig. 21, showing ten pairs of small teeth (te), which interlock to form a firm hinge. The shell is inequivalved, *i.e.*, the right valve (upper in illustration) is less concave than the left. Magnified 150 diameters.

Fig. 23. — Internal view of same scallop as in Fig. 21, showing the adductor muscle and foot, the rest of the soft parts having been removed. Scallops of this age often open the shell to an angle of 90°, thus illustrating the flexibility of the adductor muscle. Magnified 150 diameters.

Fig. 24. — Dissoconch Phase 3. View of right valve of scallop about four days after "set," showing anatomy. The left valve projects slightly beyond the right, and the hinge line is inclined slightly upward. Note increased number of gill bars. Magnified 150 diameters.



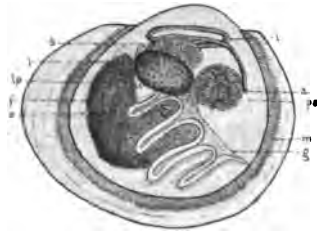
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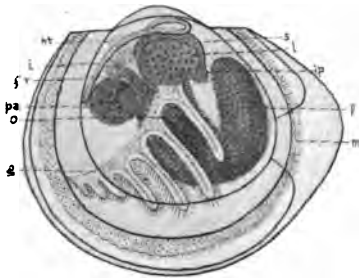
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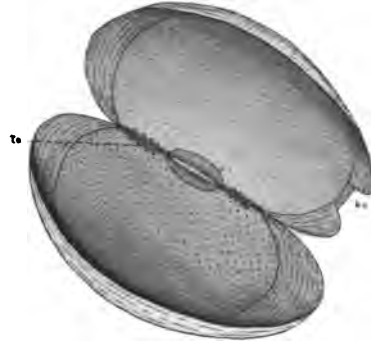
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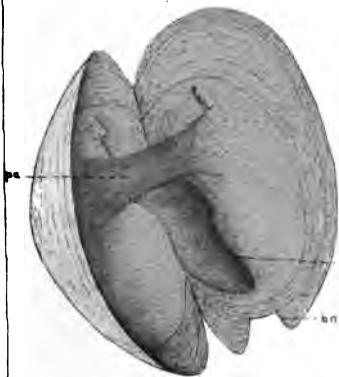
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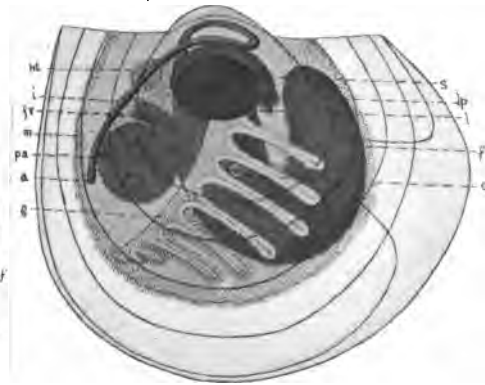
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Fig. 25. — Dissoconch Phase 4. View of right valve of scallop about one week after "set." Note contrast between the prodissoconch (pd) or embryonic shell and the succeeding dissoconch growth (d). A groove has been formed by the growth of the byssal or foot notch (bn), which is increasing in size to correspond with the development of the foot. The right valve is smaller than the left. Magnified $37\frac{1}{2}$ diameters.

Fig. 26. — View of left valve of same scallop as in Fig. 25, showing the lines of growth and the formation of the pseudo-ear, which corresponds to the location of the byssal notch. Magnified $37\frac{1}{2}$ diameters.

Fig. 27. — Same scallop as in Fig. 25, with foot extended. Anatomy shown through transparent left valve. Note increased number of gill filaments (ig) and the well-defined heart (ht). The byssal gland (bg) and cleft have become prominent on foot. The knob-like projections on the mantle are the beginnings of the tentacles (t). Magnified $37\frac{1}{2}$ diameters.

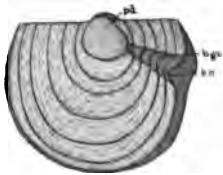
Fig. 28. — View of soft parts of slightly older scallop of Phase 4. Note the nine small tentacles (t), the two eyes (e) and the fourteen gill filaments (ig). Magnified $37\frac{1}{2}$ diameters.

Fig. 29. — Dissoconch Phase 5. Anatomy shown through transparent right valve. This stage is characterized by one tooth in the byssal notch. The scallop is represented as lying in a resting position, with mantle and foot retracted. Note the formation of eight secondary tentacles between the primary, the relative position of the eyes (e) and the tentacles (t), and the beginning of the outer gills (og). Magnified $37\frac{1}{2}$ diameters.

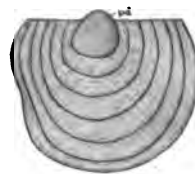
Fig. 30. — View of same scallop as shown in Fig. 29, as seen through left valve, with mantle (m) expanded and foot (f) extended. The edges of the mantle have joined posteriorly to form a pseudo-siphon (ps), through which water is expelled from the shell. The byssal gland (bg) has a prominent position on the long foot (f). Magnified $37\frac{1}{2}$ diameters.

Fig. 31. — Dissoconch Phase 6. Characterized by two teeth on the byssal notch. View of anatomy through right valve. Tertiary tentacles are developing on the edge of the mantle, which is partially extended. At this age the scallop has about twenty-two inner (ig) and ten outer (og) gill filaments. Magnified $37\frac{1}{2}$ diameters.

Fig. 32. — Scallop of same phase as in Fig. 31, lying on left valve in an unnatural position. The animal has extended his foot (f) for the purpose of turning over. The eyes (e), tentacles (t) and guard flap (mf) can be seen on the edge of the mantle. Magnified $37\frac{1}{2}$ diameters.



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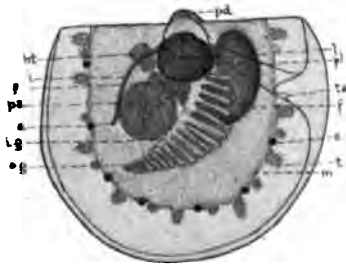
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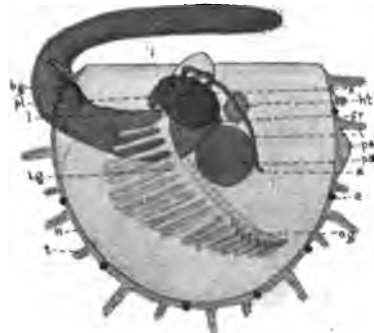
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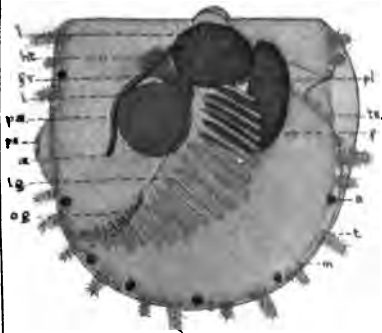
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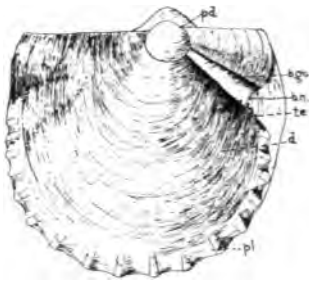
Fig. 33. — Early plicated stage. View of the right or lower valve. Note the smooth prodissoconch (pd) and dissoconch (d) areas, with the beginning of the sixteen plications (pl) of the adult. There are four teeth (te) on the byssal notch. Actual size, 1.25 millimeters ($\frac{1}{20}$ of an inch).

Fig. 34. — Same scallop as in Fig. 33, viewed from left or upper valve. Actual size, 1.25 millimeters ($\frac{1}{20}$ of an inch).

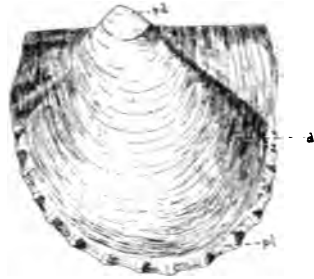
Fig. 35. — View of the anatomy of a slightly older scallop, size, 1.4 millimeters ($\frac{1}{18}$ of an inch), as seen through the right valve. Note primary, secondary and tertiary eyes (e) and tentacles (t). The outer gill (og) has about twenty-five filaments, and begins to resemble the inner gill (ig).

Fig. 36. — View of right or lower valve of same scallop as in Fig. 35. Note the five teeth (te) on the byssal notch (bn) and the beginning of the "ears" (er). The two teeth back of the external border of the byssal groove are older, and have rounded rather than the pointed ends of the last formed teeth. The valves have become nearly equal, the hinge line straight, and the byssal groove (bg) can be traced back to the asymmetrical prodissoconch. Actual size, 1.4 millimeters ($\frac{1}{18}$ of an inch).

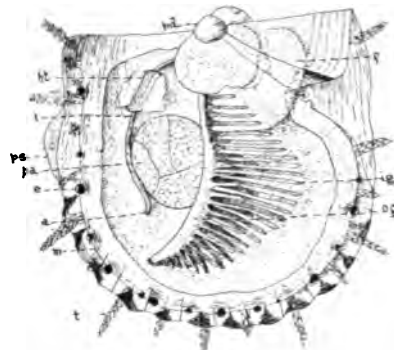
Fig. 37. — View of upper left valve of same scallop as in Figs. 35 and 36. Actual size, 1.4 millimeters ($\frac{1}{18}$ of an inch).



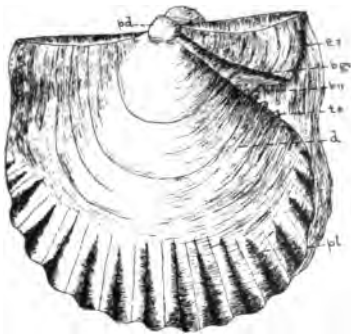
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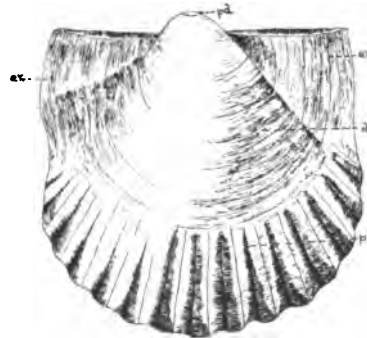
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Fig. 38. — Dorsal view of Pecten in plicated stage, showing umbones and hinge line. The left valve is deeper than the right. The prodissoconch (pd) is sharply marked off, the amount of separation between its two valves being well shown. Magnified 32 diameters.

Fig. 39. — Plicated stage. A 2.15-millimeter scallop magnified 32 diameters. View of corner of right valve, showing groove and notch. Nine teeth (te) can be seen in the byssal area, six of which are within the external border of the groove. There is a second furrow dorsal to the byssal groove, and a serrated structure near the hinge line of seven sharply pointed teeth, which possibly may be an individual variation.

Fig. 40. — Posterior view of scallop in the plicated stage, showing that the shell has become more nearly equivalvular. The plicated (pl) and dissoconch (d) areas are sharply differentiated. Magnified 32 diameters.

Fig. 41. — Prismatic structure of right valve of dissoconch shell highly magnified. This structure is not found on the left valve, or on either valve of the adult. Magnified 340 diameters.

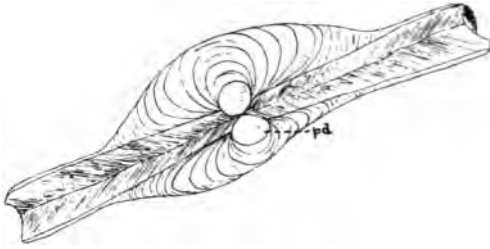
Fig. 42. — Foot of 25-millimeter (about 1 inch) scallop, showing cleft (fc), disc-like tip, byssal gland (bg) and groove (fg). Magnified 7 diameters.

Fig. 43. — Byssus of scallop of dissoconch stage after having been cast off by the animal; distal (di) or attached end; proximal (pr) or gland end. Magnified 5 diameters.

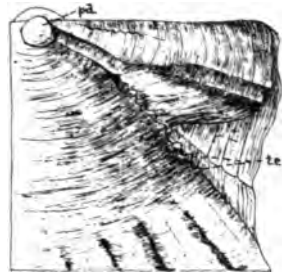
Figs. 44-46. — Stages showing the development of the tenacle. Fig. 44 represents the first appearance, Fig. 45 further development, and Fig. 46 the tip of a completely formed tenacle. The tenacles on the edge of the mantle are used as sensory, clinging and crawling organs. Magnified 110 diameters.

Fig. 47. — Scallop (4 to 5 millimeters in size) drifting just below the surface of water in aquarium (see page 60). Note the extended tentacles (t), open shell and the reverse position, with right valve uppermost. Magnified 5 diameters.

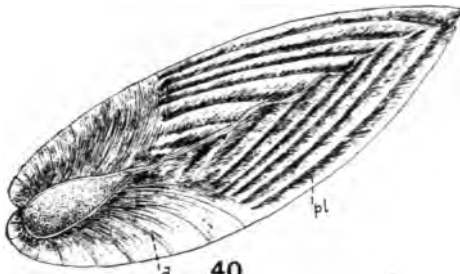
Fig. 48. — Scallop (1.5 millimeters in size) attached to eel grass by a two-stranded byssus (b), formed during the night. Magnified 7 diameters.



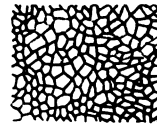
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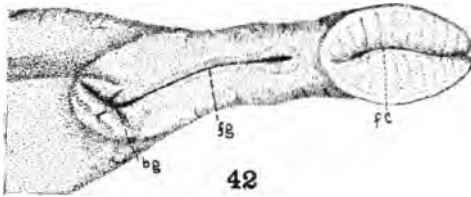
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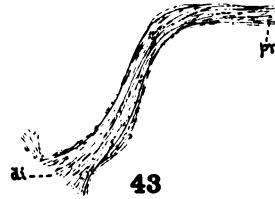
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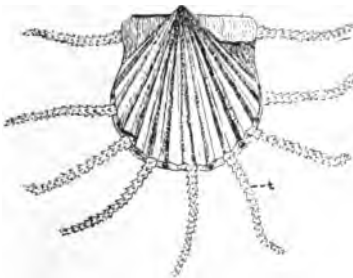
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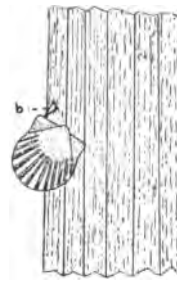
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Figs. 49-51. — Turning Over. — When lying on the left valve, as in Fig. 49, the small scallop appears uneasy, as its normal position is on the right. After a few minutes it thrusts out its foot, waves it around, as if seeking a foothold, and finally applies the cleft tip to the bottom of the glass dish with a twisting motion. By this movement the shell is so pulled that the hinge line rests upon the bottom (Fig. 50), and the scallop pries itself over, naturally falling into its normal position on the right valve.

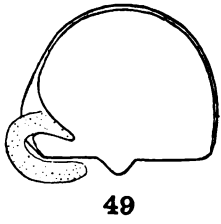
Figs. 52-54. — These figures illustrate the strength of the byssal thread, which permits the revolving of a young scallop at least 360° without breaking the strands. The scallop is shown as it is turned around on its attachment by a pencil.

Figs. 55-57. — Crawling. — In Fig. 55 the young scallop, lying on its right valve, has extended its foot, the tip of which is firmly set on the bottom. Fig. 56 shows the tipping of the shell forward by the contraction of the foot. Fig. 57 shows the completion of the movement, by which the animal has traveled three-quarters of its length, and the extension of the foot for a second pull. The action of the foot is strengthened by the clapping of the valves, which sends out a current of water from the posterior side of the shell.

Figs. 58-60. — Spinning the Byssus. — In Fig. 58 the foot is extended, with tip and byssal gland touching the bottom of the glass dish, in order to attach the byssal thread. Fig. 59 represents the spinning or drawing out of the byssal thread by the retraction of the foot toward the shell, and Fig. 60 shows the young scallop attached by one thread, while the foot is in the act of extension for the purpose of attaching a second strand at a point slightly removed from the fixation of the first. The spinning of a single thread occupies about two minutes.

Figs. 61, 62. — Swimming. — Swimming is accomplished by the alternate expulsion of water first from one "ear," as B, and then from the other, as D, which forces the scallop ahead by a series of zigzag jerks or tacks in the directions C and E respectively. (These two figures are from the illustrations of Prof. R. T. Jackson, Figs. 8, 8a, Plate XXVIII., *Memoirs Boston Society Natural History*, Vol. IV.)

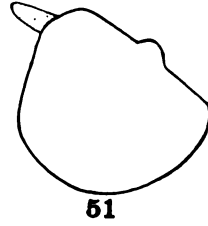
Figs. 63, 64. — These figures illustrate a manner of avoiding enemies. In Fig. 63 the scallop, when approached by a pencil at the free edge, darts quickly away in the direction of the arrow by violently expelling water from its ventral border. Darts can be likewise made in either a forward or backward direction, as shown in Fig. 64.



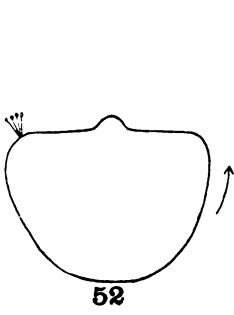
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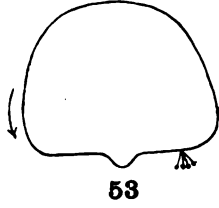
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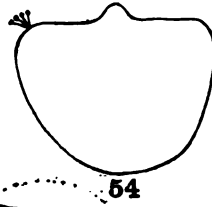
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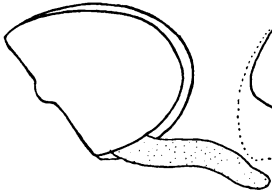
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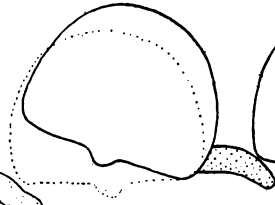
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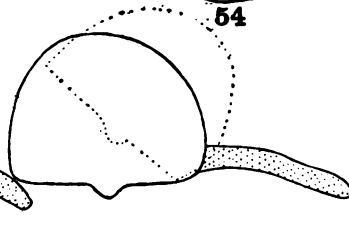
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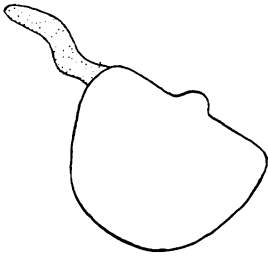
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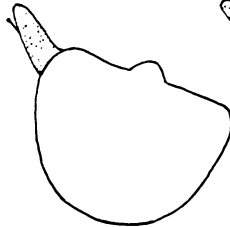
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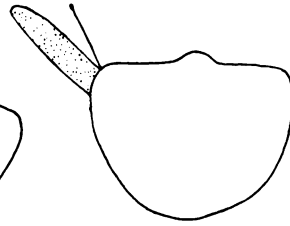
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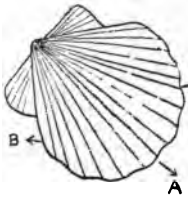
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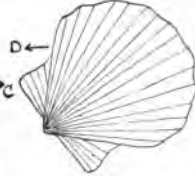
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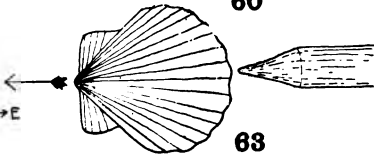
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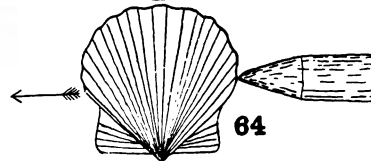
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Fig. 65. — External view of the two valves of the scallop. Left valve: A, anterior border; P, posterior border; D, dorsal border; V, ventral border (free edge); HH, hinge line; AP, width; DV, height. Right valve: U, umbo; B, byssal notch; E, ears; R, ridge; F, furrow.

Fig. 66. — Shows the method of recording the growth of individual specimens and of obtaining data upon the migratory habits of the scallop. A small hole was bored through the "ear" close to the hinge line with an awl. A numbered copper tag was attached by a fine wire.

Fig. 67. — Generative gland: ov, ovary; t, testis; ep, ciliated epithelium on surface of visceral mass; glc, gland cells; bm, basement membrane; ct, tissue of irregular cells beneath epithelium; fep, follicular epithelium; d, ciliated ducts, the one in the testis containing spermatozoa, and on its walls a gland cell being shown; bv, blood vessel. (This illustration is a copy of a drawing by James L. Kellogg, produced as Fig. 71, Plate LXXXIX., Bulletin, United States Fisheries Commission, 1890, and is published with the consent of Dr. Kellogg. Unfortunately, in the reduction much of the fine detail of the original has been lost.)

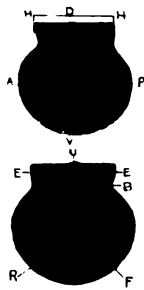
Fig. 68. — The oyster drill (*Urosalpinx cinerea*). An enemy of the scallop, which bores a fine hole through the shell and feasts upon the soft parts. Cases containing the eggs of this mollusk are shown on the right. Life size.

Fig. 69. — **Scallop Food.** — Typical diatoms found in Massachusetts waters. (a, b, c) *Navicula*, (d, e) *Pleurosigma*, (f) *Nitzschia*, (g) *Melosira*, (h) *Chaetoceras*, (i) *Cyclotella*, (j) *Licmophora*. Magnified 200 diameters.

Fig. 70. — A starfish opening a scallop by slowly dragging the valves apart by means of small, sucker-like feet on the lower side of each of the five rays or "arms." When the valves are forced apart the starfish rolls out its stomach, which envelops the soft body of the scallop. Digestive juices are poured forth and the food is digested outside the body of the starfish. This creature is the most destructive natural enemy of the scallop, and in certain localities has made serious inroads. It is best killed by steaming or bringing ashore.

Fig. 71. — Diagram of the wire cages in which scallops were suspended from the raft at Monomoy Point. The cage consists of a framework of wood covered with $1\frac{1}{2}$ -inch mesh wire netting.

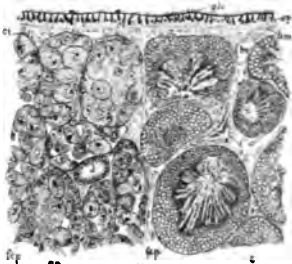
Fig. 72. — Plankton net, made of silk bolting cloth, used to catch the swimming shellfish larvæ. The net is towed through the water behind a rowboat.



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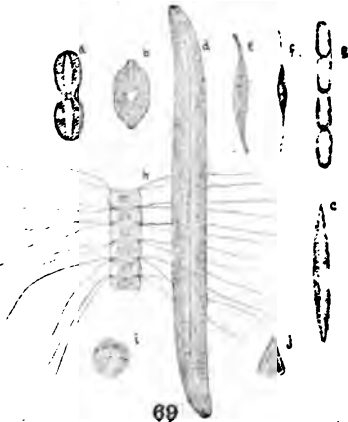
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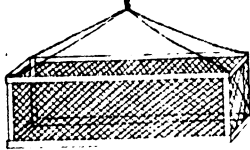
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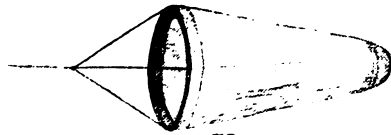
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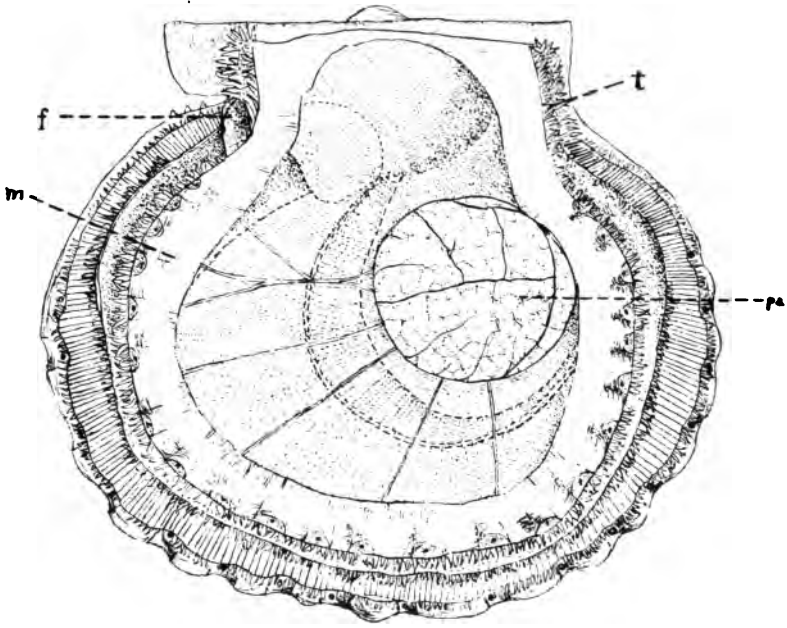


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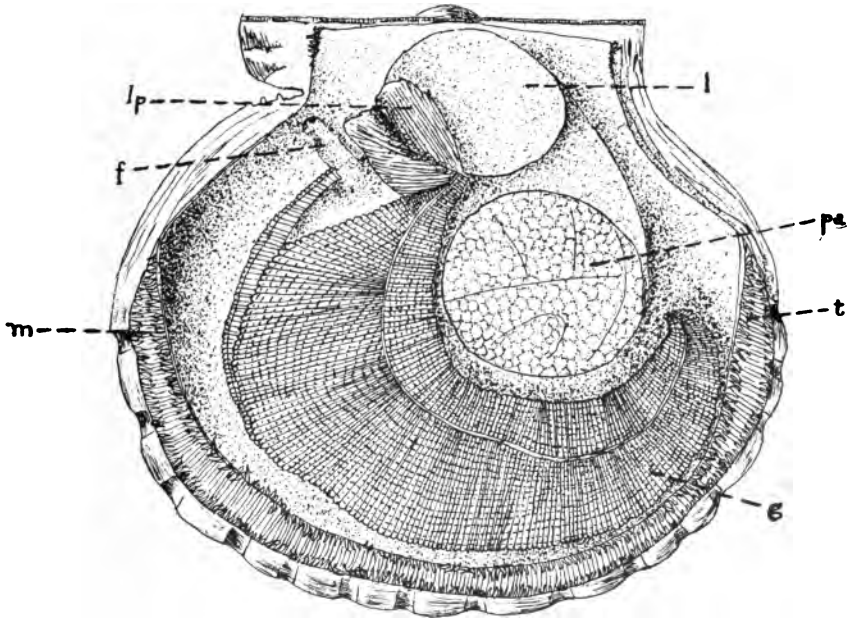
In general, the organs of *Pecten* lie at three different layers, viz., valve, mantle and gills. Figs. 73, 74 and 75, which are one and one-quarter times the natural size, represent the views disclosed as each of these layers is successively cut away.

Fig. 73. — View of *Pecten* with left valve removed. The gills (g), liver (l) and palps (lp) are represented in dotted lines as they are seen through the transparent mantle. As the left lobe of mantle (m) has been detached from the shell, it has contracted. The right mantle (m) lobe is shown fully extended.

Fig. 74. — View of *Pecten* with left valve and mantle removed, showing gills (g), palps (lp), foot (f) and liver (l).



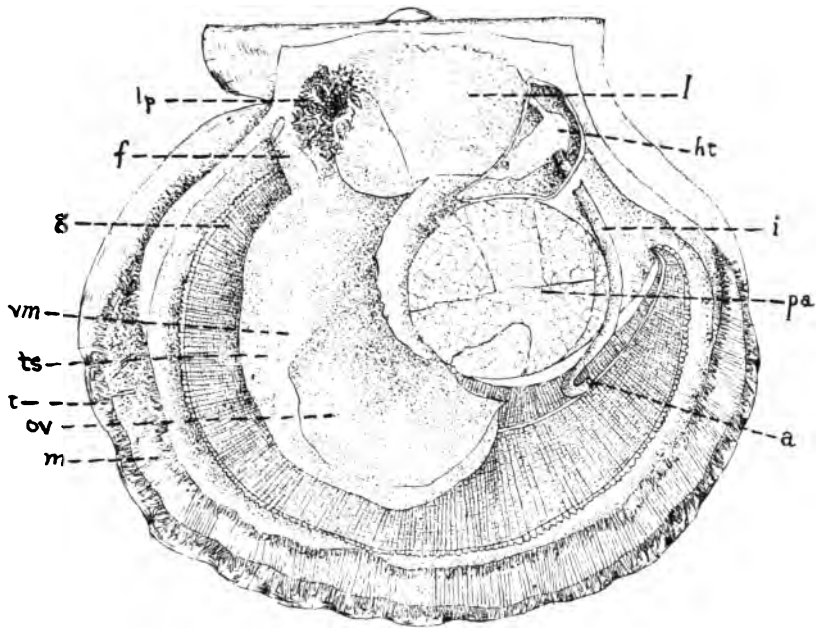
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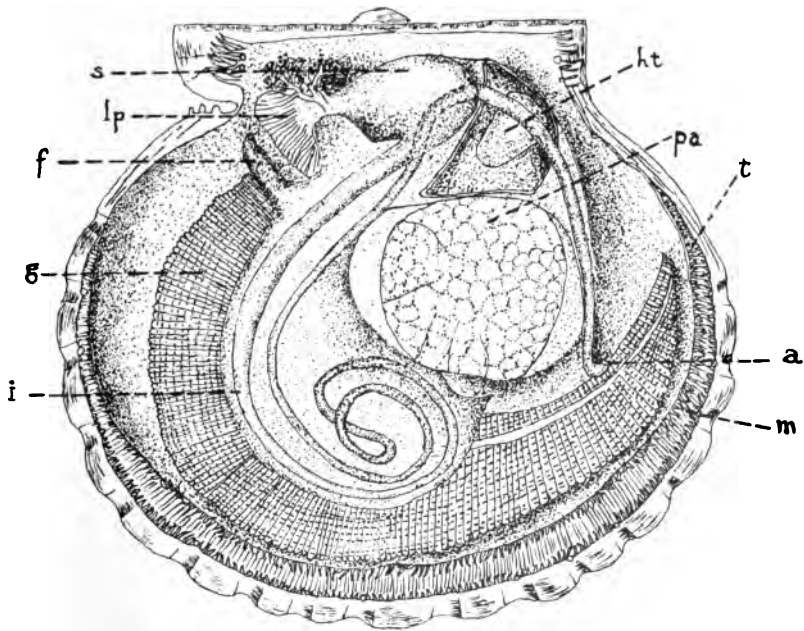
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Fig. 75. — View of Pecten with left valve, mantle (m) and gills (g) removed, showing the heart (ht), visceral mass (vm) and reproductive organs.

Fig. 76. — View of Pecten, showing the digestive system.



75



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Fig. 77. — Changes in form of shell. A series of drawings illustrating the changes from the early veliger (the first shell), which is $\frac{1}{10}$ of a millimeter in size, to a 2-millimeter scallop. Note (a) change from flat-hinged veliger (1) to the prodissoconch (2), with prominent umbones; (b) return to a straight hinge (3), width greater than height; (c) width and height become equal (8); (d) formation of "ears" (10).

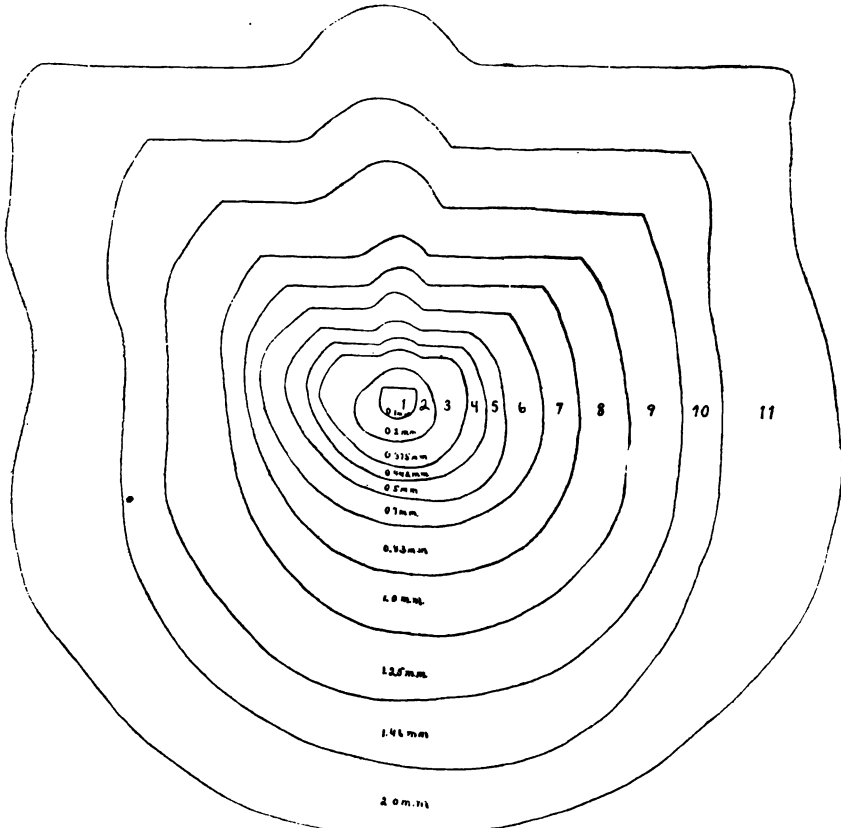


Fig. 78. — Map of the Massachusetts coast, showing the distribution of the shallow-water scallop (*Pecten irradians*). The scalloping grounds are indicated by the black areas.

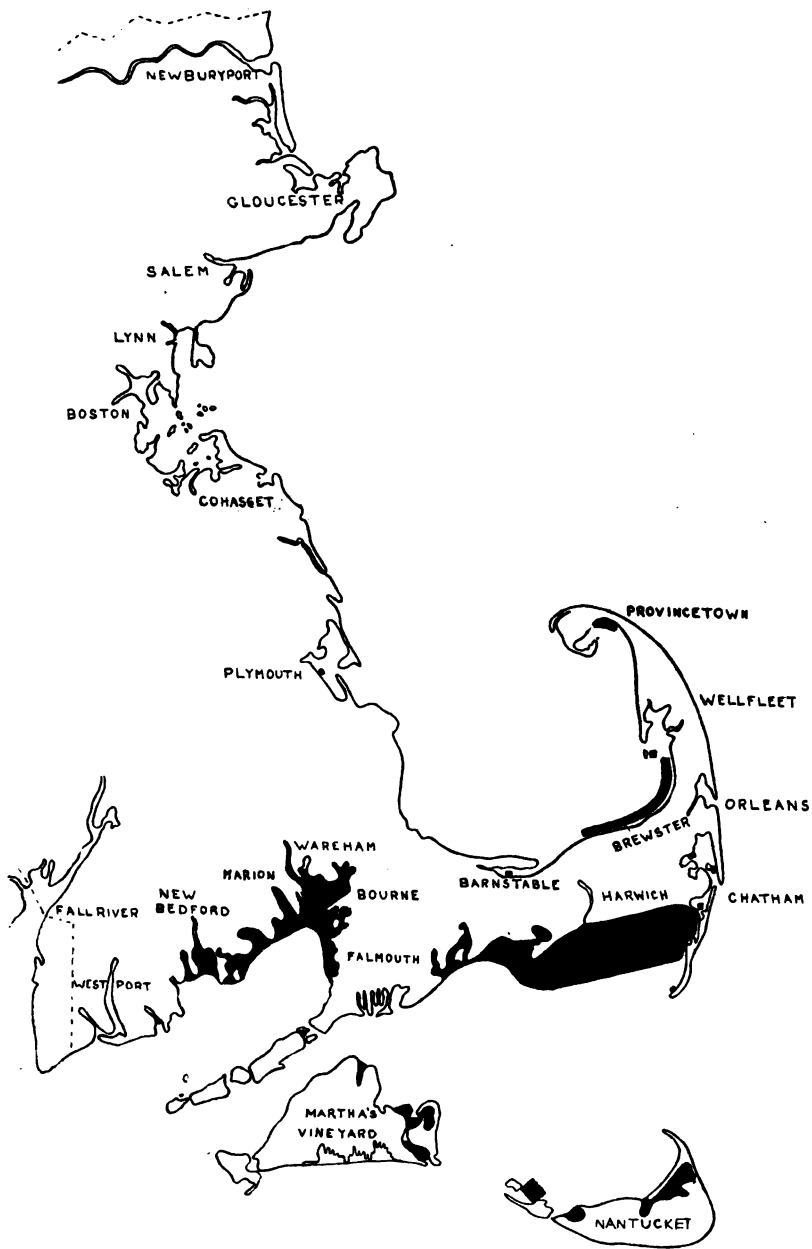
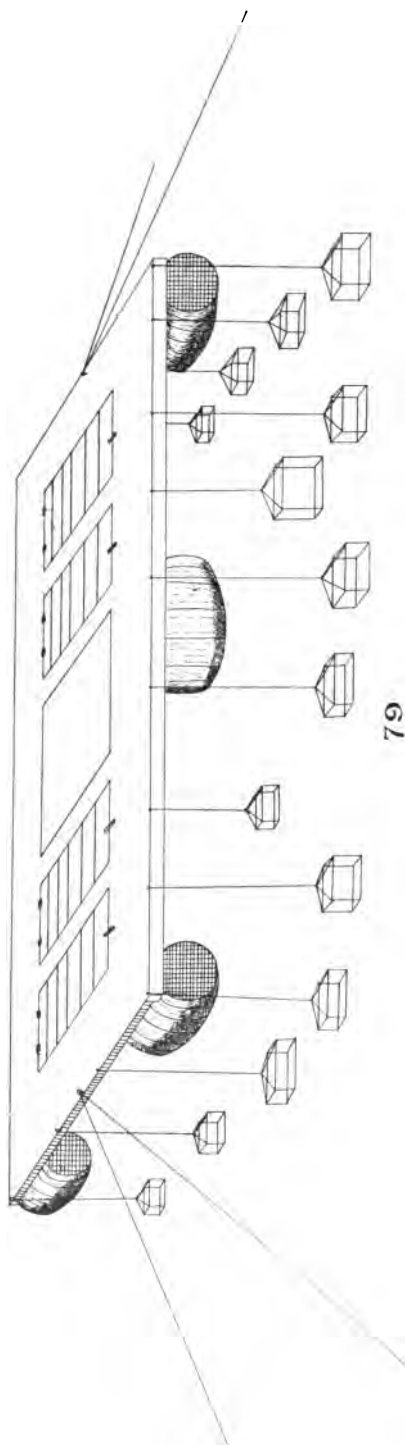


Fig. 79. — Plan of biological raft used at Monomoy Point for growth experiments and spat collecting. The raft, 20 feet long by 10 feet wide, provided with a central well and four trap-doors, was anchored in the Powder Hole in 20 feet of water. Wire cages and wooden boxes were suspended at various depths from the raft. Many kinds of mollusks were caught and raised in these spat boxes. The raft proved particularly useful in the study of the post-embryonic life history, as the scallops "set" in large numbers on the boxes, cages and ropes, where specimens could be obtained in all stages of development for laboratory examination. Also, many interesting growth experiments upon the quahaug, scallop and clam were conducted in the sand boxes.



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Fig. 80. — Type of pen used in determining the rate of growth of the scallop. The sizes ranged from 40 to 400 square feet. The posts were made of 2 by 3 foot joists, fixed in the soil and placed at sufficient intervals to hold the netting firmly in position. Wire netting ($1\frac{1}{4}$ -inch mesh) and old seines of a suitable height were stretched around the posts.

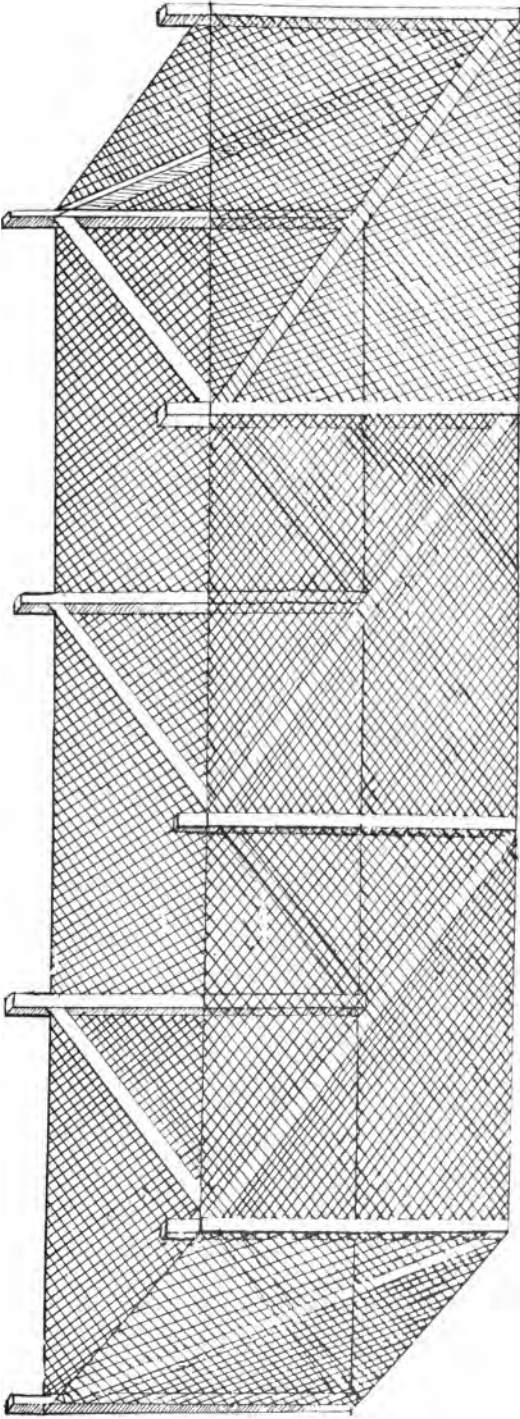


Fig. 81. — Chart of the daily temperatures for the month of June, taken at the Powder Hole at Monomoy Point in 1906 and 1907. The average of the daily temperatures at 1, 10 and 20 feet, taken at 6 A.M., 12 M. and 6 P.M., is given. The great irregularity of the curve is due to the fluctuation of this small body of water with changes in the temperature of the air. The season of 1907 was nearly two weeks behind that of 1906, as during the early part of June the temperature was from 8° to 10° colder, but by June 19 the two became approximately the same as is shown by the intersection of the curves on the chart. The principal fact shown by the plot is the location of the "spawning" temperature, or the temperature necessary for spawning. In 1906 the scallops first spawned on June 12, in 1907 on June 21. In each case spawning did not occur until the water reached the temperature of $61\frac{1}{2}^{\circ}$, although there was nine days' variation between the two years.

Fig. 82. — **The Food Value of the Scallop.** — The relative proportion, by weight, of the various parts of the average scallop is graphically represented by a series of rectangles, corresponding to (1) the total weight, 1.5 ounces, or 100 per cent.; (2) total non-edible part, 1.23 ounces, or 82.23 per cent., which includes both shell and non-edible soft part; (3) shell, .74 of an ounce, or 49.43 per cent.; (4) non-edible soft part, .49 of an ounce, or 32.8 per cent.; (5) actual food, .27 of an ounce, or 17.77 per cent.

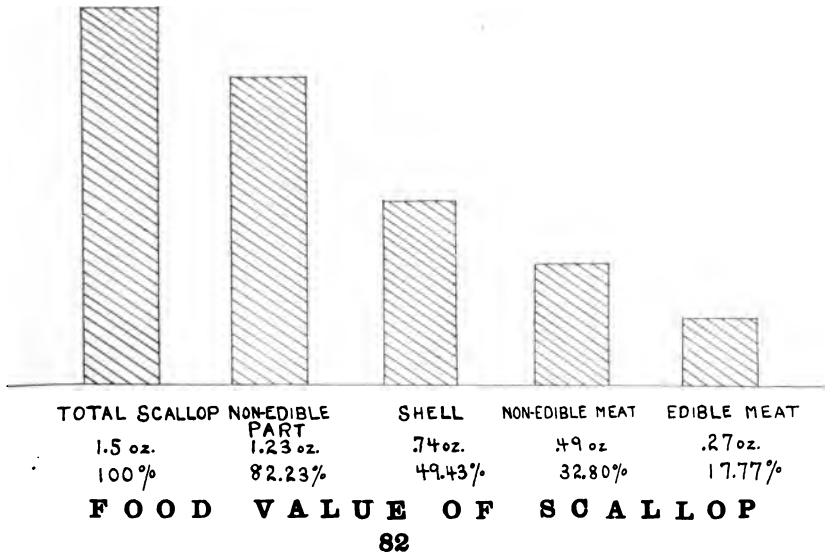
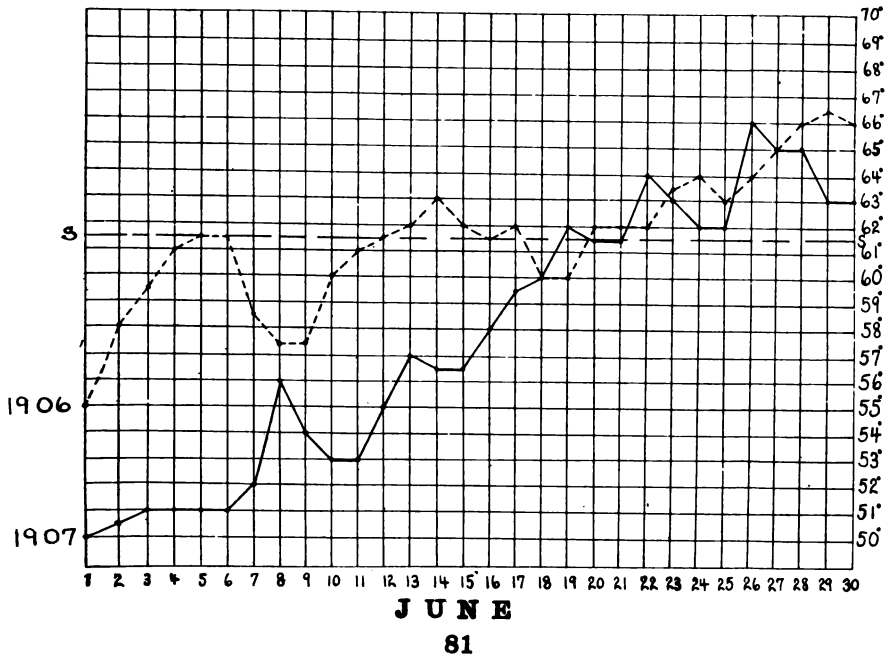
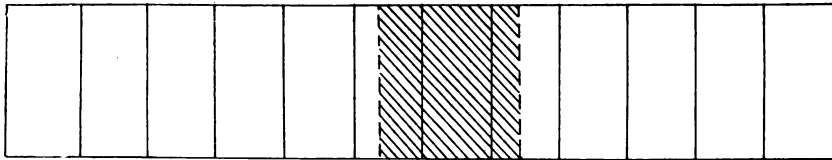


Fig. 83. — The Spawning Months. — The spawning season lasts from the second week in June to the middle of August. This period is represented by the shaded portion.

Fig. 84. — The Growing Months. — The scallop increases in size of shell only during the summer months, as during the winter growth ceases. The shaded portion represents the period of growth.

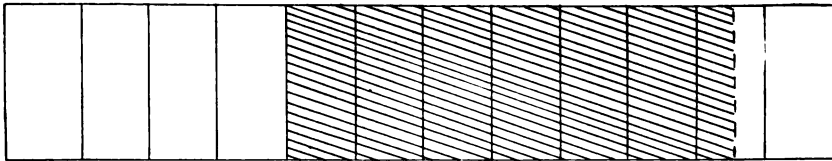
Fig. 85. — The Relative Value of the Growing Months. — The scallop does not increase with equal rapidity during the seven months of growth. The relative value of these months is graphically represented in terms of the increase in volume during each month for a standard scallop. The slow growth during June and July, as represented by the short columns, roughly corresponds to the spawning season, and the decrease in growth is probably due to that cause.



JAN. FEB. MAR. APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.

SPAWNING MONTHS

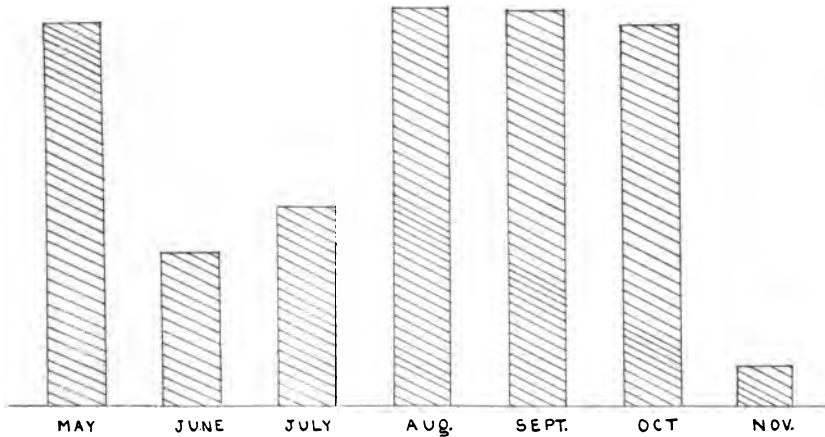
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JAN. FEB. MAR. APRIL MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.

GROWING MONTHS

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MAY JUNE JULY AUG. SEPT. OCT. NOV.

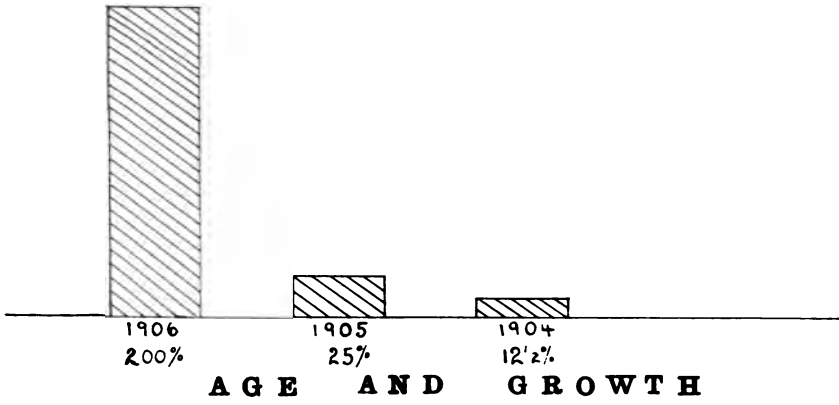
**RELATIVE VALUE
OF GROWING MONTHS**

85

Fig. 86. — Age and Growth. — As the scallop becomes larger the rate of growth, both in actual increase and gain in volume, becomes less. The three columns represent the comparative gain in volume of (1) "seed" scallops ($\frac{3}{4}$ of an inch) of the 1906 set, 200 per cent.; (2) fourteen-month scallops of the 1905 set, 25 per cent.; (3) twenty-six month scallops of the 1904 set, 12 per cent., under the same conditions.

Fig. 87. — Current and Growth. — The three columns represent the volumetric growth, for a definite period, of scallops in good, medium and poor currents, and are formulated from measurements made at Stage harbor, Chatham, in 1906–07. At the mouth of the harbor is a large eel-grass flat, extending from the shore to the channel. The flat was arbitrarily divided into three areas, according to the circulation of water: (1) near the channel (good current); (2) half-way to shore (medium current); (3) near shore (poor current); and the rate of growth of the 1906 set was followed in each division. These figures demonstrate the great importance of current in scallop growth.

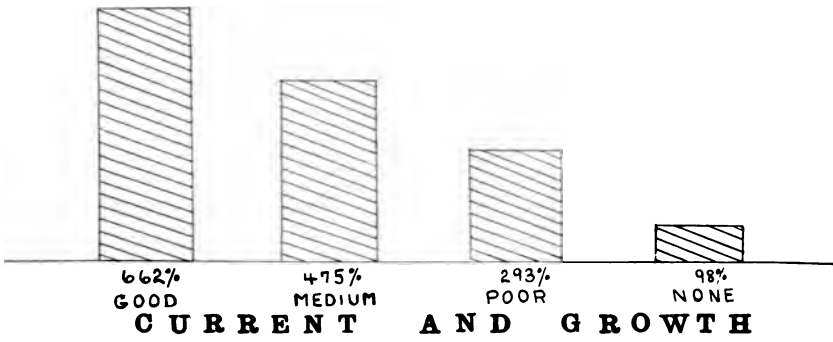
Fig. 88. — Current and Growth. — The influence of current is again illustrated by comparing the volumetric growth of "seed" scallops of the same size at (1) the raft, Monomoy Point (good current), 662 per cent.; (2) Stage harbor, Chatham (medium current), 475 per cent.; (3) south side of Powder Hole, Monomoy Point (poor current), 293 per cent.; (4) east side of Powder Hole (no current), 98 per cent. The comparative volumetric growth for a period of seventy-six days during the summer of 1906 is represented for each of these localities by the shaded columns. A knowledge of the relation of current to growth should prove valuable to the prospective scallop culturist.



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Fig. 89. — Temperature and Growth. — The broken line represents the curve of the average monthly temperature of the water during the year 1906 at the Powder Hole, Monomoy Point, and the numbers on the sides indicate the degrees. The other curve represents the growth of the 1905 scallop set during the year 1906, and the same figures which corresponded to the degrees in temperature now stand for the size of the scallop in millimeters (25.4 millimeters equal 1 inch). Tracing the growth of the scallop, size 34 millimeters, January 1, no growth is noticed until May 1, when the water assumes a temperature of about 49° F. During the month of May there is a rapid growth, which slackens during June and July, the spawning months, as is shown by the drop in the curve, and is again resumed during August, September and October. The growth perceptibly slackens during November, and probably ceases altogether after the middle of the month, when the water is about 43° F. To all practical purposes the growth ceases November 1, at a temperature of 49° F., which is directly comparable to temperature of the water when growth began, May 1. Therefore, it is apparent that the growth of the scallop, as typified by shell formation, depends upon the temperature of the water, at least 45° F. being necessary for growth. The cessation of growth is not due to any decided fall in the food supply but rather to the inactivity of the scallop, which becomes sluggish in cold water.

Growth (Millimeters).

May 1,	34.00	September 1,	51.00
June 1,	39.71	October 1,	56.80
July 1,	42.12	November 1,	62.28
August 1,	45.10	December 1,	62.90

Fig. 90. — The plotting shows the comparative growth of large and small scallops of the same age during their second summer. Division B (38.50 millimeters) by the end of the season has gained the greater part of the difference at the start between it and Division A (49.50 millimeters), reducing the margin from 11 to 3.27 millimeters. These scallops were confined in the same pen, and numbered Division A 125, Division B 200. This tendency perhaps accounts for the uniformity in size of scallops in any particular locality at the end of the second summer's growth, when the scallop is ready for market.

Growth (Millimeters).

	A.	B.		A.	B.
May 1,	49.50	38.50	September 5,	56.72	51.90
June 1,	52.25	43.25	September 25,	59.79	55.67
July 10,	53.55	46.25	November 3,	62.88	59.46
August 1,	54.80	47.85	November 22,	63.00	59.73

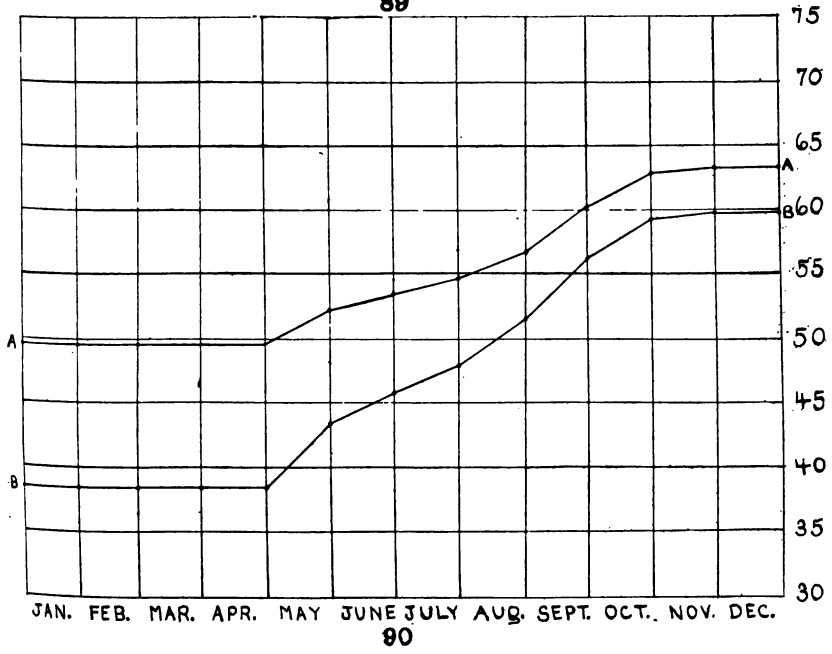
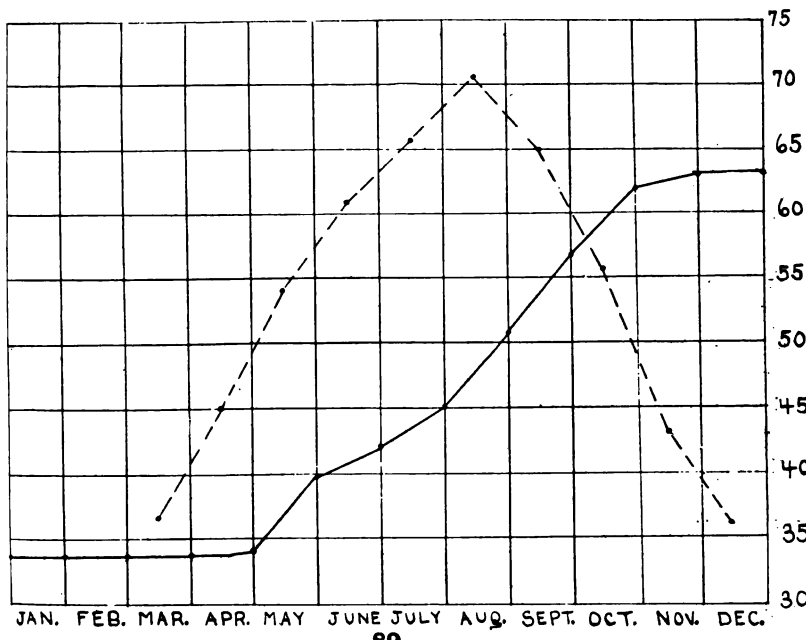


Fig. 91. — The curve represents the growth of the average Massachusetts scallop from 1905 to 1907. Notice the rapid growth from July to December in 1905, and the complete cessation during the winter months. During the second summer comes another period of rapid growth, which ceases about Dec. 1, 1906. The normal life of these scallops ends some time in March or April, 1907, but a few often pass the two years' mark. The growth of these old scallops is represented by the broken line in the diagram, summer growth starting about May 1. The figures on the right represent the size of the scallops in millimeters (25.4 millimeters equal 1 inch).

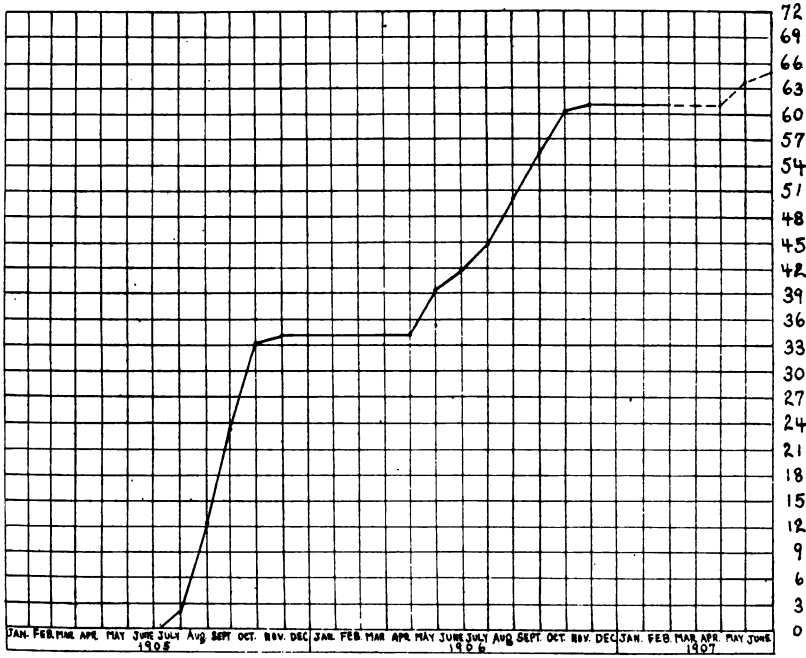
Average Scallop (Millimeters).

Aug. 1, 1905,	2.00	Aug. 1, 1906,	44.57
Sept. 1, 1905,	12.66	Sept. 1, 1906,	50.08
Oct. 1, 1905,	23.20	Oct. 1, 1906,	55.51
Nov. 1, 1905,	33.11	Nov. 1, 1906,	60.68
Dec. 1, 1905,	34.24	Dec. 1, 1906,	61.27
May 1, 1906,	34.24	May 1, 1907,	61.27
June 1, 1906,	39.51	June 1, 1907,	63.93
July 1, 1906,	41.77	July 1, 1907,	65.07

Fig. 92. — The three curves, A, B and C, represent the growth of the average scallop in the three localities of Buzzard's Bay, Cape Cod and the islands of Martha's Vineyard and Nantucket, respectively. For convenience, the start is considered as uniform, although there is several days' difference in the spawning season. The difference in growth at the various dates can be determined by referring to the figures on the right, which represent the size of the scallop in millimeters (25.4 millimeters equal 1 inch).

Growth (Millimeters).

DATE.	C.	B.	A.
	The Islands.	The Cape.	Buzzard's Bay.
August 1,	2.00	2.00	2.00
September 1,	10.48	12.52	15.03
October 1,	18.93	22.88	27.86
November 1,	26.71	32.65	39.97
December 1,	27.60	33.76	41.35
May 1,	27.60	33.76	41.35
June 1,	33.44	39.03	46.27
July 1,	35.90	41.25	48.34
August 1,	38.95	44.00	50.92
September 1,	45.98	49.43	56.01
October 1,	50.91	54.28	61.03
November 1,	56.50	59.83	65.73
December 1,	57.13	60.40	66.27
May 1,	57.13	60.40	66.27
June 1,	60.01	63.04	68.73
July 1,	61.28	64.15	69.77



91



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Fig. 93. — Graphic representation of the growth of the average scallop and its gain in volume. Starting September 1 with 1 bushel of $\frac{1}{2}$ -inch scallops, the increase in volume is represented on the right in terms of bushels, corresponding to the different sized scallops on the left: (1) two-month scallop, .5 of an inch, 1 bushel; (2) three-month scallop, .91 of an inch, 7.3 bushels; (3) five-month scallop, 1.34 inches, 26.5 bushels; (4) thirteen-month scallop, 1.75 inches, 62 bushels; (5) seventeen-month scallop, 2.41 inches, 185.6 bushels. The scallops are drawn one-half actual size. This rapid increase shows the benefit of preserving the "seed" scallop, as the yield in large scallops will more than repay the fisherman for his foresight.

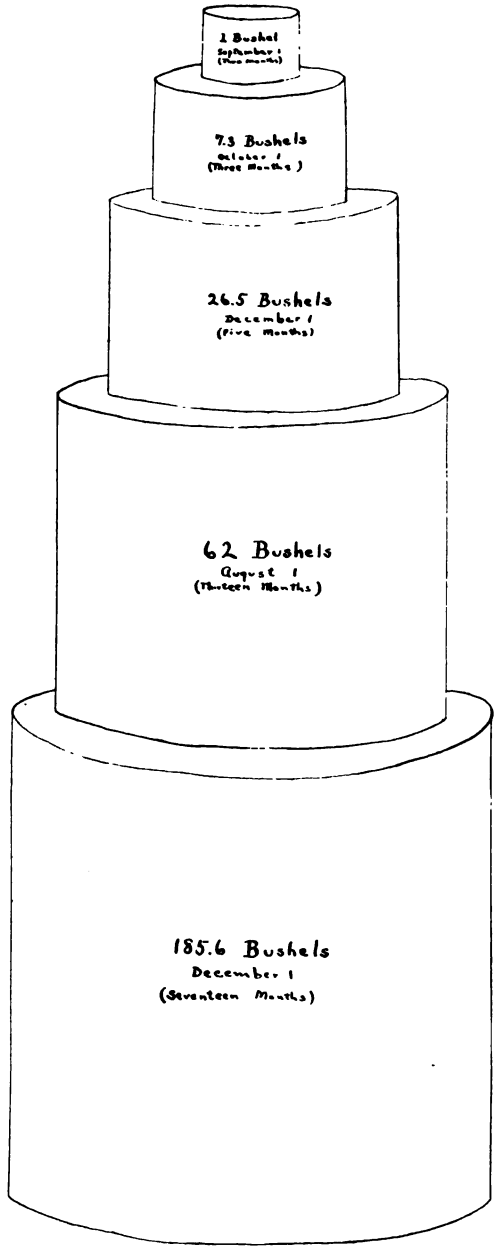
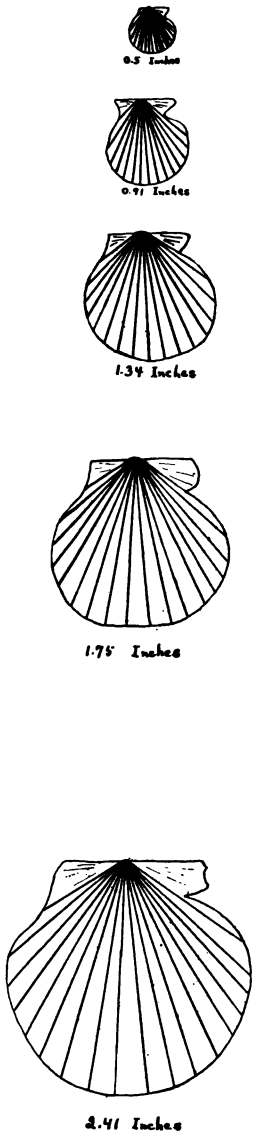


Fig. 94. — *Nassa obsoleta* (the little black winkle of the tide flats) devouring a scallop. These little scavengers swarm over the scallop. Occasionally one is active enough to get between the valves, forming a wedge which permits the entrance of others, which quickly consume the scallop. Owing to the alertness of the scallop and its different habitat (*Nassa* usually being found on the tide flats) little damage is done.

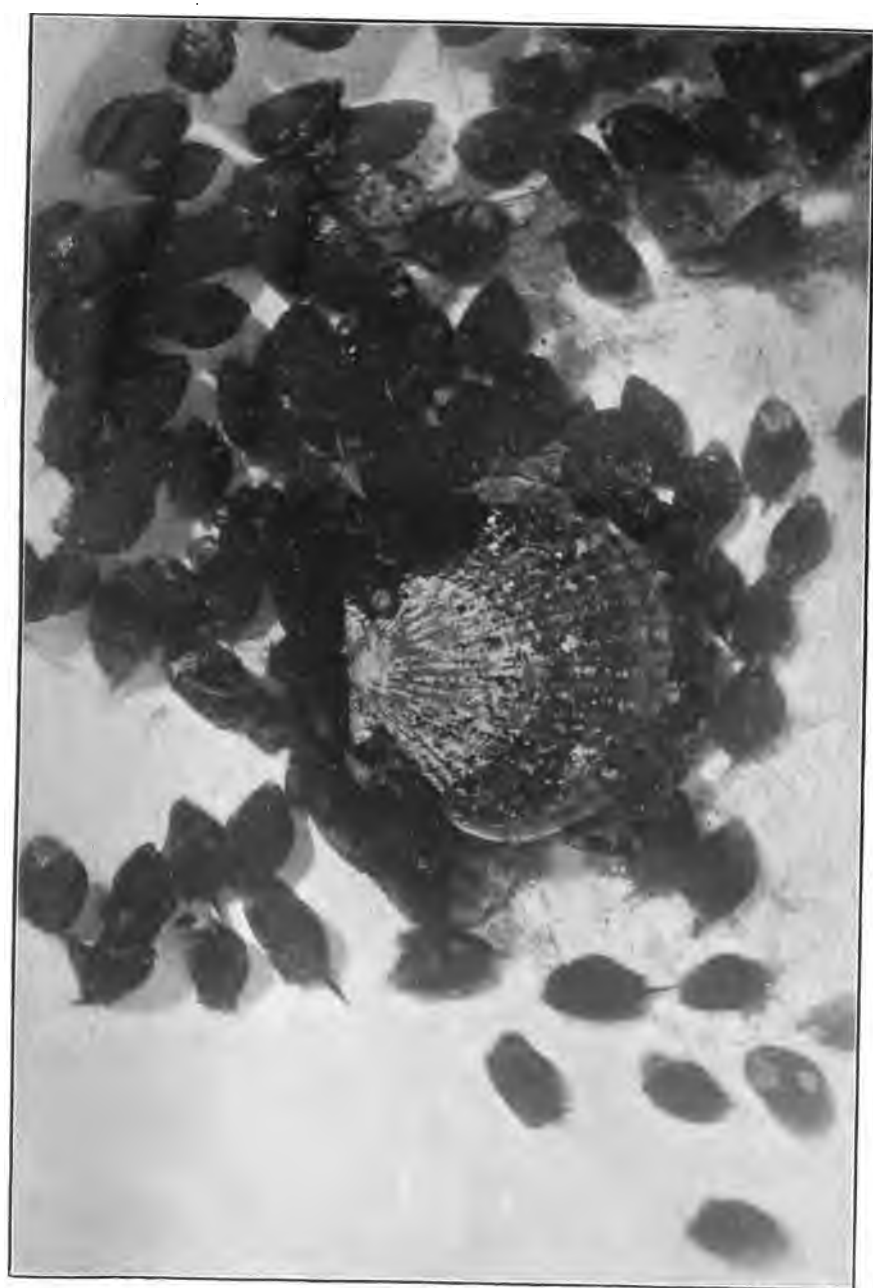


Fig. 95. — The oyster drill (*Urosalpinx cinerea*) boring the shell of a scallop. Five drills were found on this specimen, but one rolled off when the photograph was taken. The drill bores a fine hole through the shell by means of a ribbon-like tongue lined with saw-like teeth, and then sucks out the contents.



Fig. 96. — Spat boxes, lowered from the raft at Monomoy Point, after having been down for the summer. Notice the quantity of barnacles and silver shells (*Anomia*) which have collected on the outside. Inside these boxes heavy sets of clams and quahaugs were obtained, while on the outside were found numbers of young scallops, which were removed before the photograph was taken.



Fig. 97. — Method of recording the spawning of the scallop. W. G. Vinal, following the spawning of individual scallops, placed them in separate glass dishes. In this artificial way the time and manner of spawning could be determined, and the eggs obtained for artificial fertilization. Spawning was accomplished by raising the temperature of the water.






Fig. 98. — Young oysters, about three months old, attached to the upper valve of living scallops, taken at Wellfleet in October, 1908. As these oysters increase in size they prove detrimental to the welfare of the scallops, and finally may cause their death.



Fig. 99. — Scallops over one year old, as shown by the formation of the annual growth line, which is caused by cessation of growth during the winter months. Any scallop which does not possess this annual growth line is less than one year old, and is a "seed" scallop. The present legal definition of a "seed" scallop is based on the annual growth line, as its absence indicates that the animal has not as yet reached its spawning season, and is, therefore, an immature animal.



Fig. 100. — “Seed” scallops, with a small amount of white worm tube (*Serpula*) attached to the shell. These scallops have not yet spawned, and, for the future welfare of the scallop fishery, should be protected until they have passed the spawning period, which occurs when the scallop is one year old. The capture of these immature scallops is a decided menace to the fishery, and is forbidden by law.

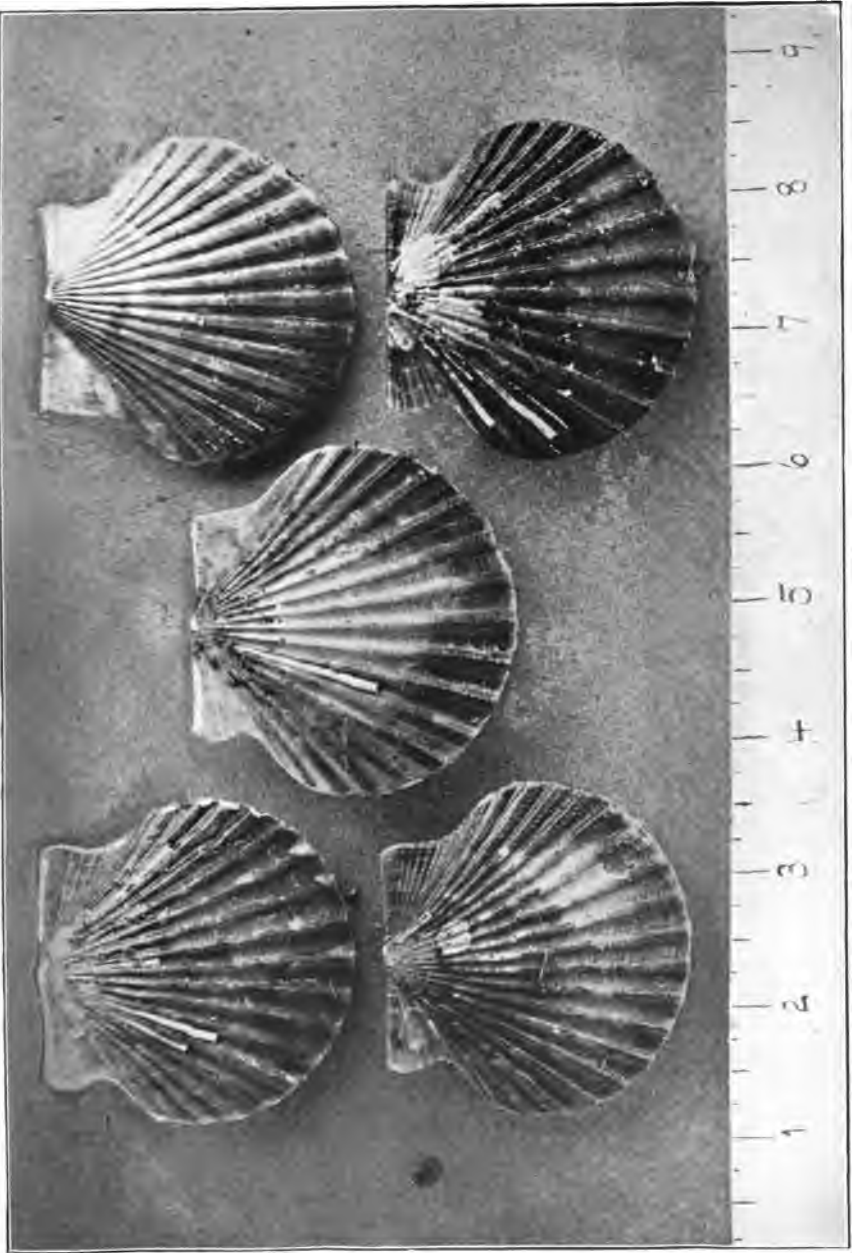


Fig. 101. — Variation in size of scallops. The two on the left are fifteen months old, while the two on the right are "seed" scallops three months old. The difference in size in scallops of the same age, especially in different localities, renders impossible the definition of a "seed" scallop by means of a size limit.

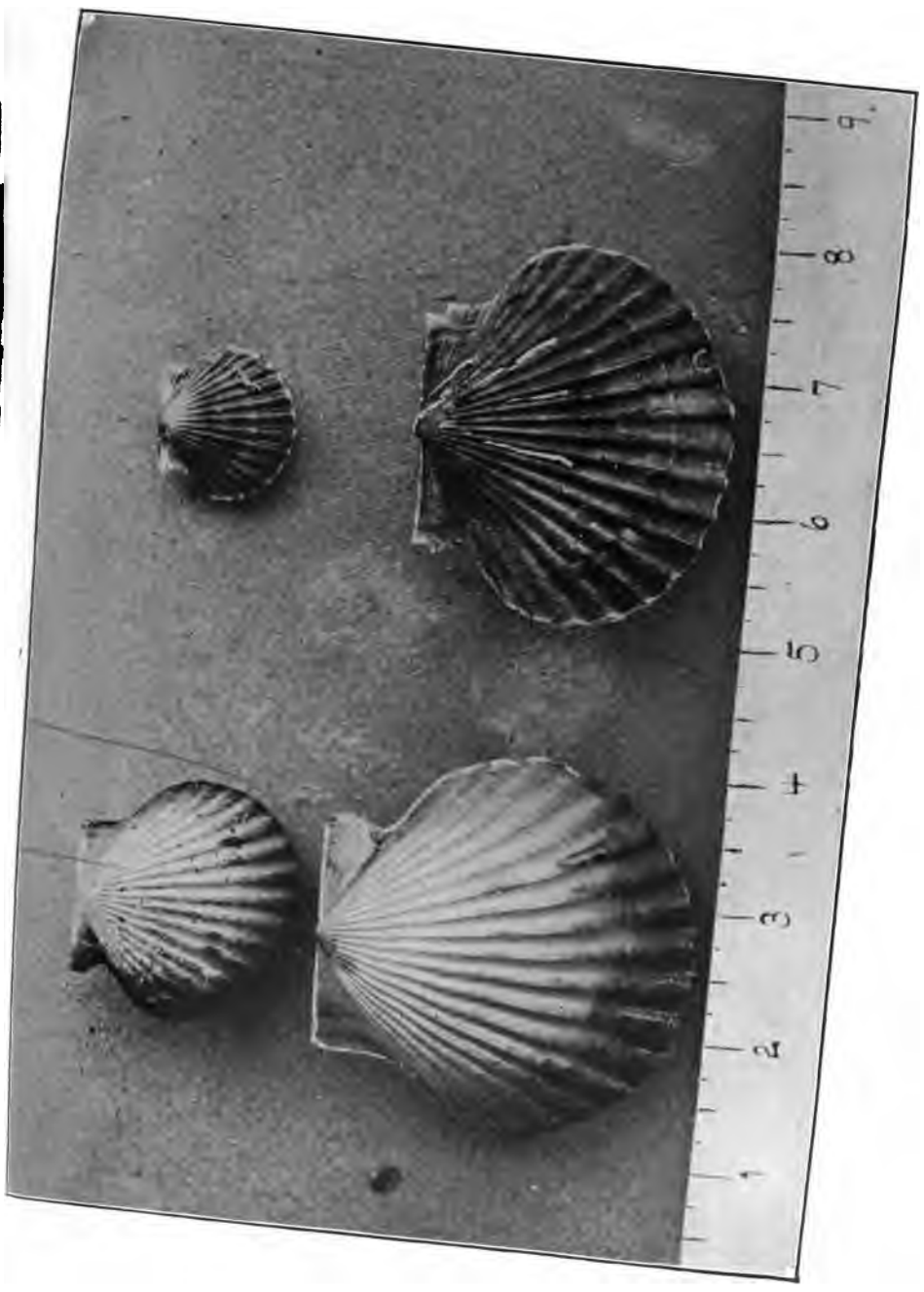


Fig. 102. — Young, yearling and two-year-old scallops. The small scallops on the left are three months old "seed;" those in the center are eleven months old, and have a growth line near the edge of the shell; while the large scallops on the right are twenty-three months old, and have two growth lines, the second being close to the edge of the shell. About one-half life size.

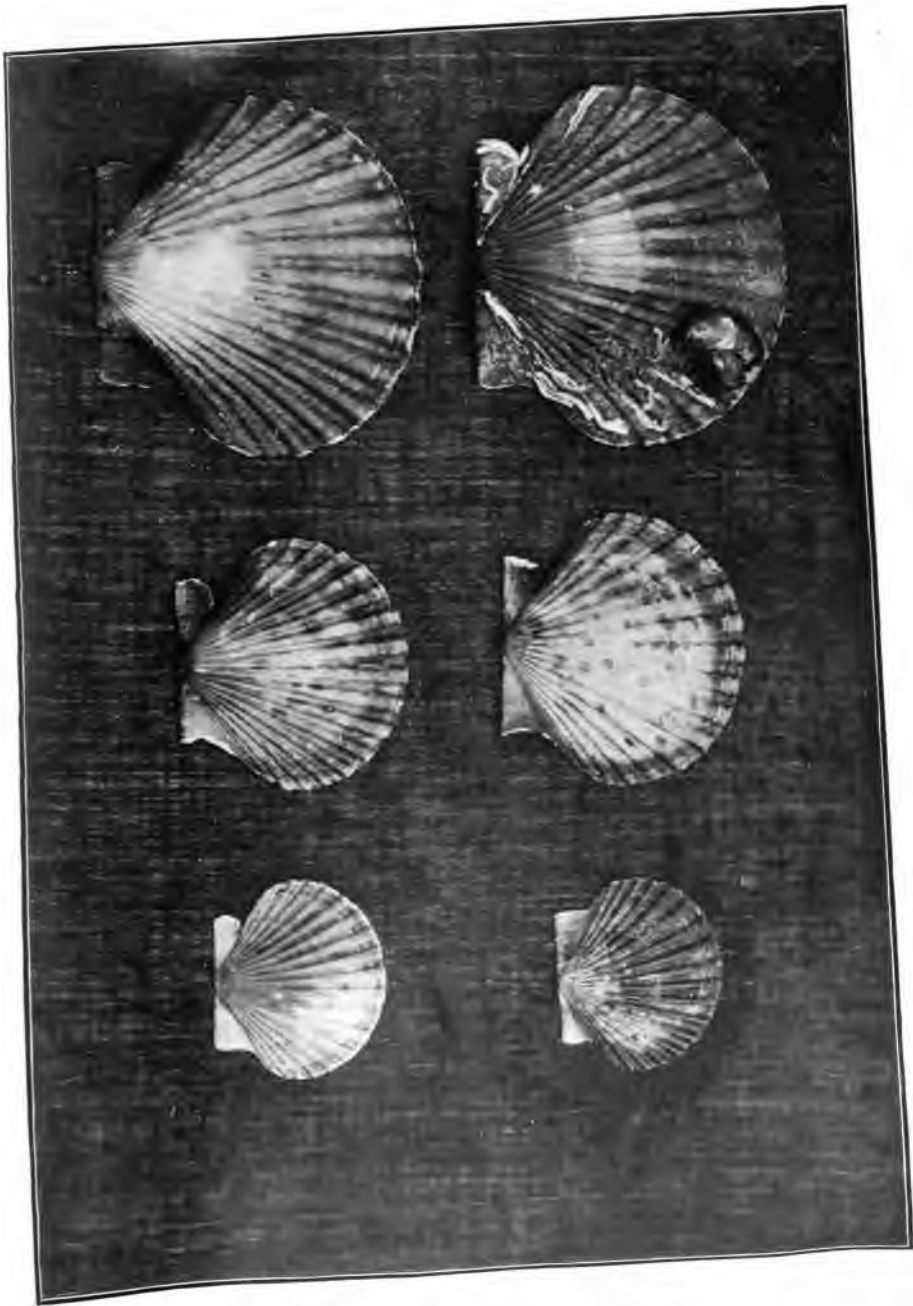


Fig. 103. — The scallop on the left, as indicated by the arrow, has been killed by the oyster drill, which has pierced the shell with a fine hole. A year-old oyster is attached to the scallop in the center, while a *Crepidula* (quarterdecker) has fastened on the scallop on the right.



Fig. 104. — These scallops show two or three lines which indicate temporarily arrested growth. A careful distinction should be made between such lines and the annual growth line, which is caused by the non-growth of the scallop during the winter months, appearing about May 1.

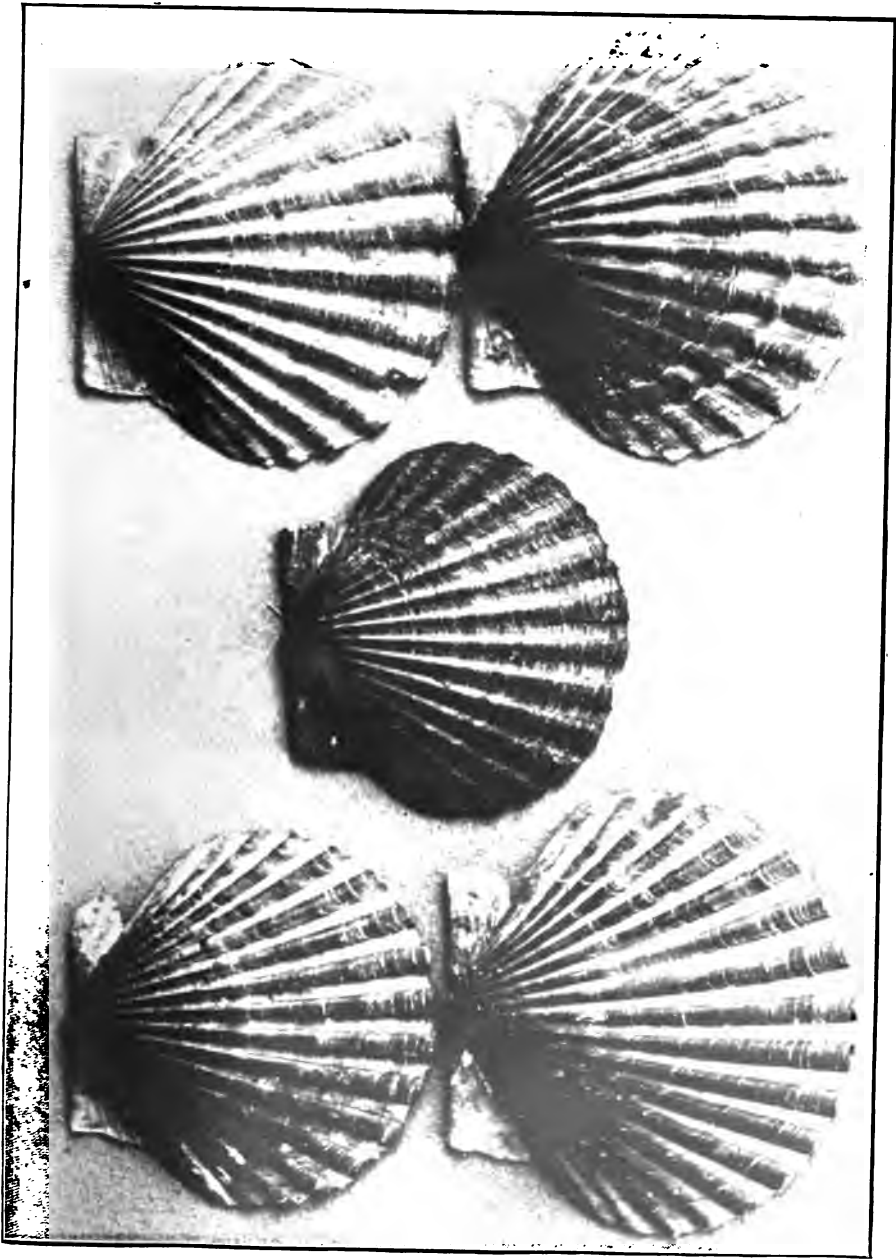


Fig. 105. — Instrument used for measuring the scallops. The scallop is passed down the triangle until it touches on both sides, where the figures indicate its length in millimeters (25.4 millimeters to an inch). The instrument possesses the advantage of speed and accuracy for quick measuring, as many as 1,200 measurements being possible in an hour.



Fig. 106. — The two scallops, each fourteen months old, illustrate the difference in growth between localities with good and poor circulation of water. The scallops situated in the "current" receive more food than in the still water, and naturally have a faster growth, as is shown by the greater size of the "current" scallop.



Fig. 107. — The Scallop Pusher. — This implement consists of a wooden pole, from 8 to 9 feet long, attached to a rectangular iron framework, 3 by 1½ feet, fitted with a netting bag 3 feet in depth. The scalloper, wading in the shallow water, gathers the scallops from the flats by shoving the pusher among the eel grass. The photograph shows the correct position of the pusher in operation. Only a small part of the pole is shown.

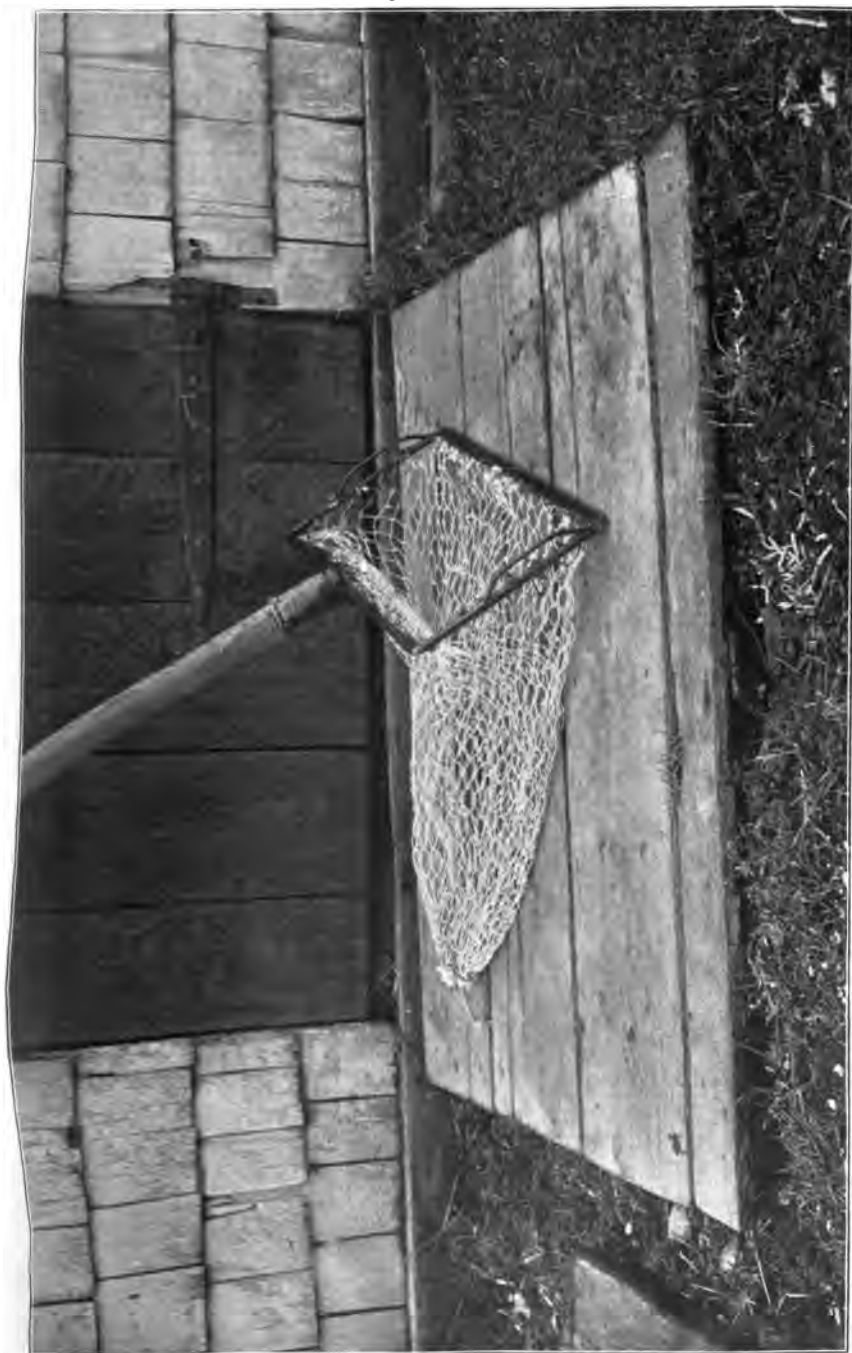


Fig. 108. — Scallop Dredge, — "The Scraper." — This implement has the form of a triangular iron framework, with a curve of nearly 90° at the base, to form the bowl of the dredge. On the upper side a raised crossbar connects the two arms, while at the bottom a strip of iron 2 inches wide extends across the dredge. This narrow strip acts as a scraping blade, and is set at an angle so as to dig into the soil. The top of the net is fastened to the crossbar and the lower part to the blade. The usual dimensions of the dredge are: arms, 2½ feet; upper crossbar, 2 feet; blade, 2½ feet. The net varies in size, usually running from 2 to 3 feet in length and holding between 1 and 2 bushels. Additional weights can be put on the crossbar when the scalloper desires the dredge to "scrape" deeper. A wooden bar 2 feet long buoys the net. The scraper used at Nantucket has the entire net made of twine, whereas in other localities the lower part consists of interwoven iron rings.



Fig. 109. — Scalping boats between the wharves at Nantucket. The cat-boats are moored in this fashion after the day's dredging.

Fig. 110. — The start. Leaving for the scalping grounds.



Fig. 111. — The scalloping fleet at work on the beds.
Fig. 112. — "Dredging."



Fig. 113. — Emptying the contents of the dredge on the "culling" board, where the scallops are separated from the eel grass and other débris.

Fig. 114. — "Culling."



Fig. 115. — Landing the catch on the wharf.

Fig. 116. — Carrying the scallops to the shanties, where they are opened.



Fig. 117. — Shell heap outside the shanties at the end of the season.

Fig. 118. — The finished product, packed in kegs, ready for shipment to market.

NOTE. — Figs. 109–118 are from an excellent series of photographs furnished by Mary H. Northend, Salem, Mass.



